US006553150B1

(12) **United States Patent**
Wee et al.

(10) **Patent No.: US 6,553,150 B1**
(45) **Date of Patent: *Apr. 22, 2003**

(54) **IMAGE SEQUENCE COMPRESSION FEATURING INDEPENDENTLY CODED REGIONS**

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(73) Assignee: **Hewlett-Packard Development Co., LP**, Houston, TX (US)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/557,797**

(22) Filed: **Apr. 25, 2000**

(51) **Int. Cl.**[7] **G06K 9/36**; H04N 7/087; H04N 5/222; H04N 7/12

(52) **U.S. Cl.** **382/243**; 382/239; 348/722; 348/473; 375/240.08

(58) **Field of Search** 382/243, 238, 382/236, 239; 375/240.12, 240.15, 240.08, 240.26; 348/473, 722; 341/55; 345/719

(56) **References Cited**

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Sikora, T, "The MPEG–4 Video Standard Verification Model", (Feb. 1997), IEEE Transactions On Circuits and Systems For Video Technology, vol. 7, No. 1, pp. 19–31.

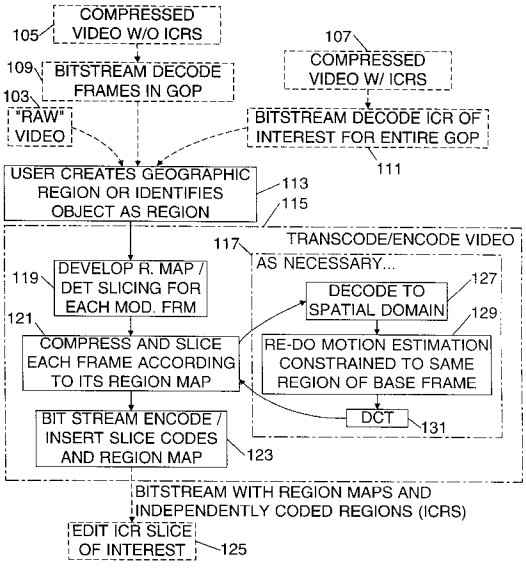
* cited by examiner

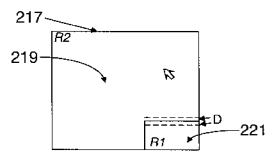
Primary Examiner—Wenpeng Chen
(74) *Attorney, Agent, or Firm*—Marc P. Schuyler

(57) **ABSTRACT**

In a MPEG or other video coding system, regions of each frame may be independently coded for later, independent extraction or processing directly from a compressed bit stream. An encoder/transcoder receives raw video, standard compressed video or compressed video already having independently coded regions ("ICRs") that are to be edited in some manner. The encoder/transcoder permits user creation of regions, and provides automatic tracking features to identify and select those objects or regions through multiple frames (notwithstanding object movement). The encoder/transcoder re-uses as much compressed input data as is available in generating an output, and so, may be used for real-time encoding and editing processes. To this effect, the encoder/transcoder re-uses original bit stream data as well as original or new motion vector data in compiling an output, or any mix of them as appropriate.

21 Claims, 14 Drawing Sheets





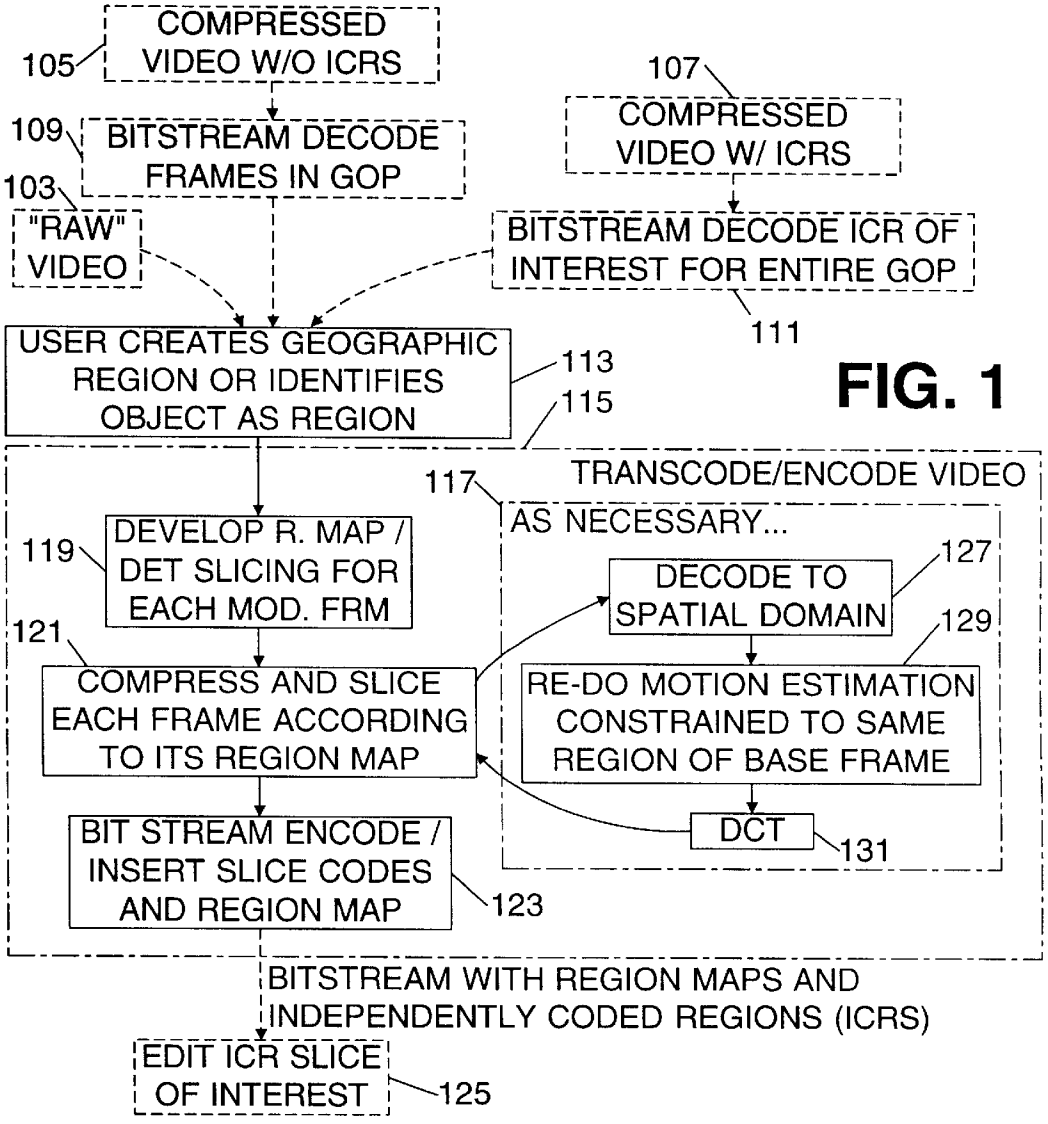

COMPRESSED VIDEO W/O ICRS
105
BITSTREAM DECODE FRAMES IN GOP
109
"RAW" VIDEO
103
107
COMPRESSED VIDEO W/ ICRS
BITSTREAM DECODE ICR OF INTEREST FOR ENTIRE GOP
111
USER CREATES GEOGRAPHIC REGION OR IDENTIFIES OBJECT AS REGION
113
115
TRANSCODE/ENCODE VIDEO AS NECESSARY...
117
DEVELOP R. MAP / DET SLICING FOR EACH MOD. FRM
119
DECODE TO SPATIAL DOMAIN
127
121
COMPRESS AND SLICE EACH FRAME ACCORDING TO ITS REGION MAP
RE-DO MOTION ESTIMATION CONSTRAINED TO SAME REGION OF BASE FRAME
129
DCT
131
BIT STREAM ENCODE / INSERT SLICE CODES AND REGION MAP
123
BITSTREAM WITH REGION MAPS AND INDEPENDENTLY CODED REGIONS (ICRS)
EDIT ICR SLICE OF INTEREST
125

FIG. 1

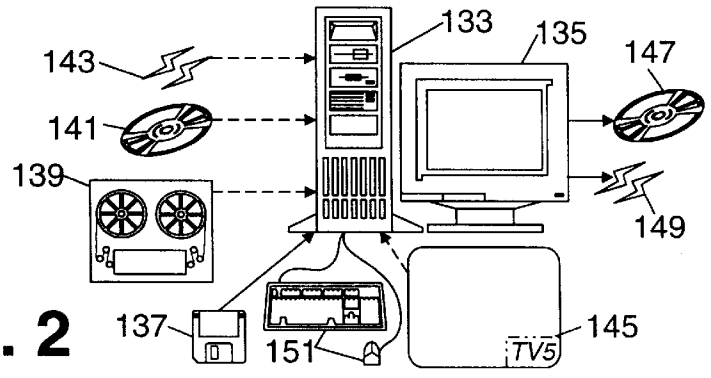

133
135
147
143
141
139
149
137
151
145
TV5

FIG. 2

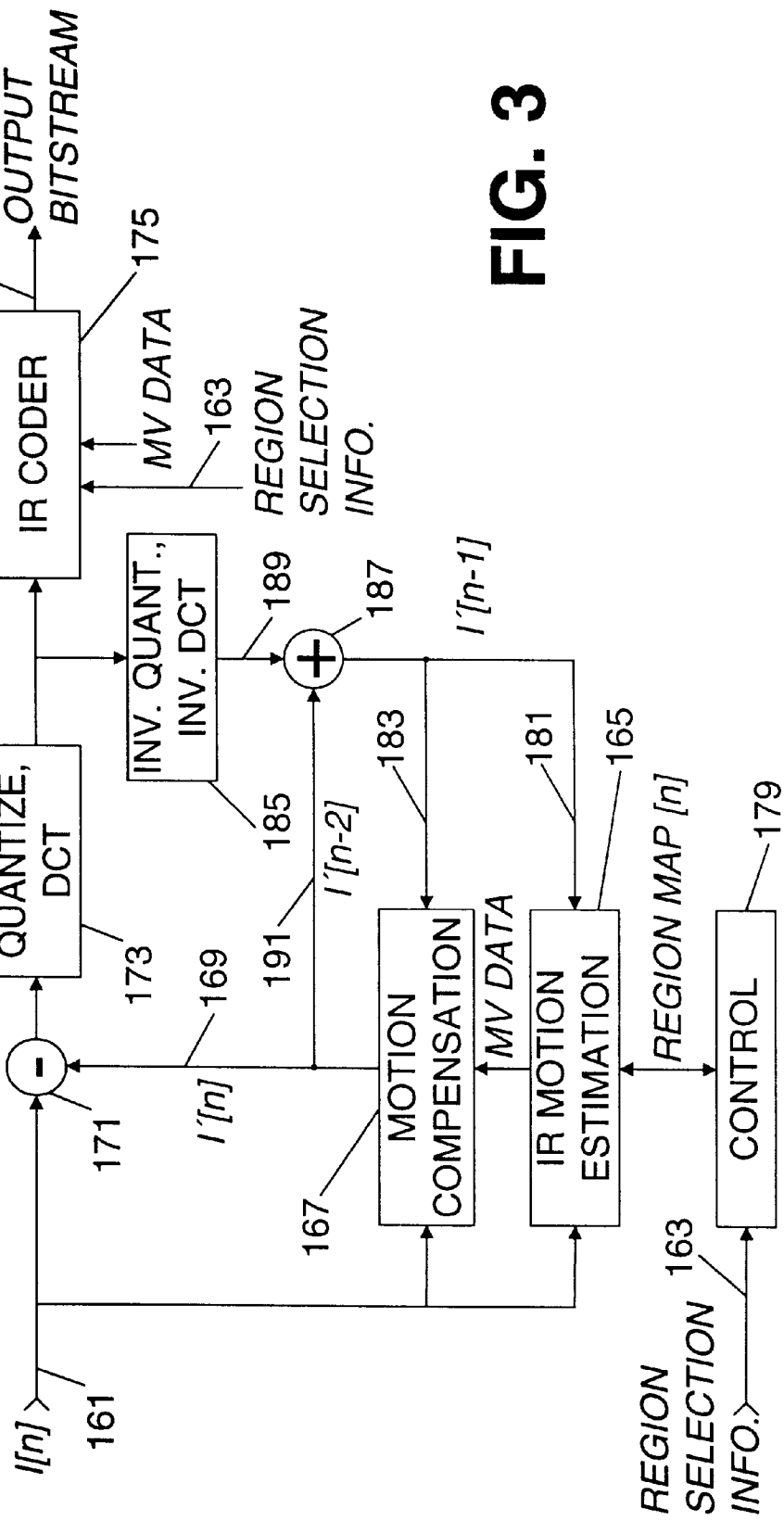

OUTPUT BITSTREAM
177
175
IR CODER
MV DATA
163
REGION SELECTION INFO.
INV. QUANT., INV. DCT
189
187
I´[n-1]
QUANTIZE, DCT
185
183
181
165
173
169
191
I´[n-2]
MOTION COMPENSATION
MV DATA
IR MOTION ESTIMATION
REGION MAP [n]
CONTROL
179
171
I´[n]
167
163
I[n]
161
REGION SELECTION INFO.

FIG. 3

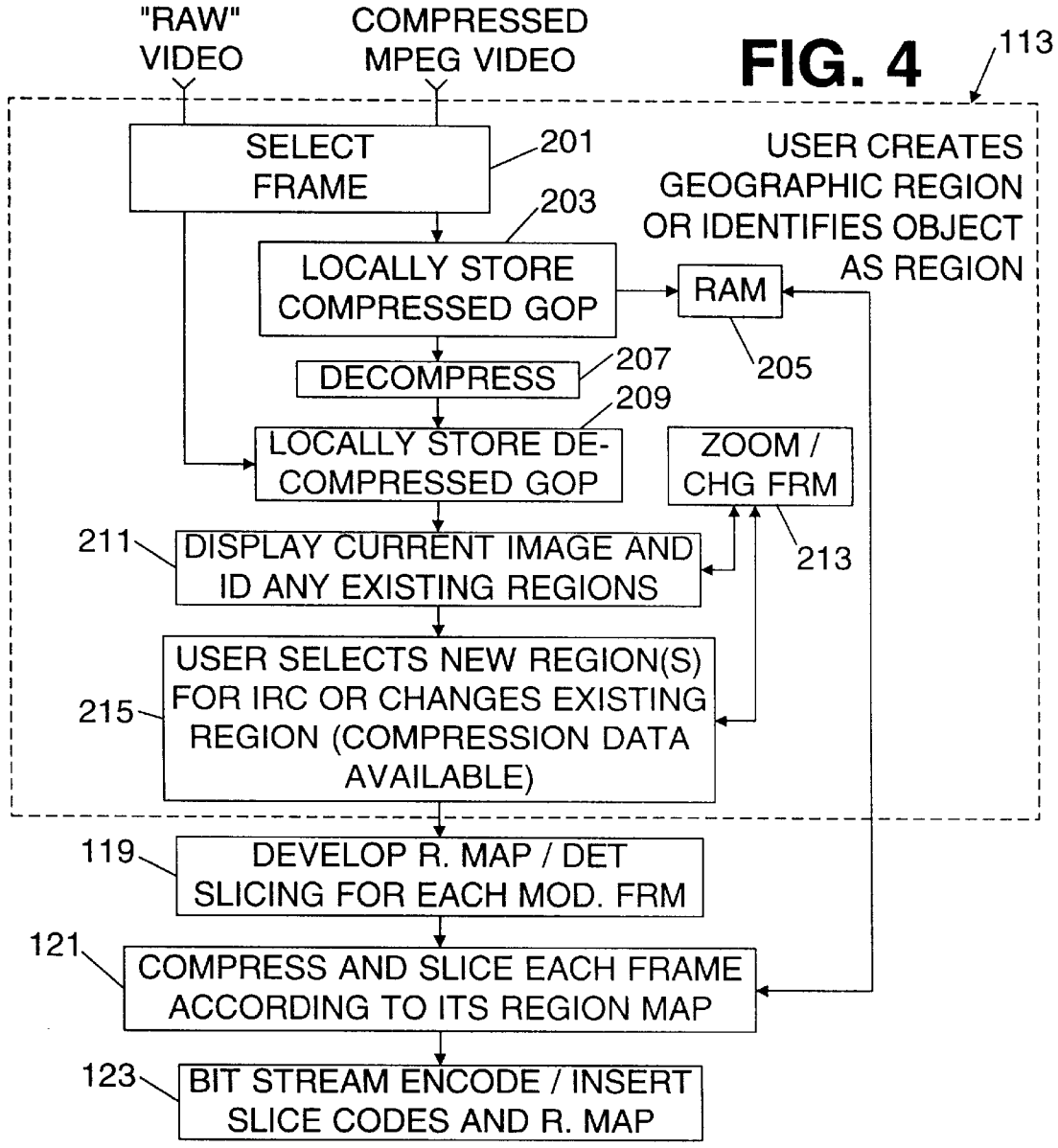

"RAW" VIDEO
COMPRESSED MPEG VIDEO
113
SELECT FRAME
201
USER CREATES GEOGRAPHIC REGION OR IDENTIFIES OBJECT AS REGION
203
LOCALLY STORE COMPRESSED GOP
RAM
205
DECOMPRESS
207
209
LOCALLY STORE DE-COMPRESSED GOP
ZOOM / CHG FRM
213
211
DISPLAY CURRENT IMAGE AND ID ANY EXISTING REGIONS
215
USER SELECTS NEW REGION(S) FOR IRC OR CHANGES EXISTING REGION (COMPRESSION DATA AVAILABLE)
119
DEVELOP R. MAP / DET SLICING FOR EACH MOD. FRM
121
COMPRESS AND SLICE EACH FRAME ACCORDING TO ITS REGION MAP
123
BIT STREAM ENCODE / INSERT SLICE CODES AND R. MAP

FIG. 4

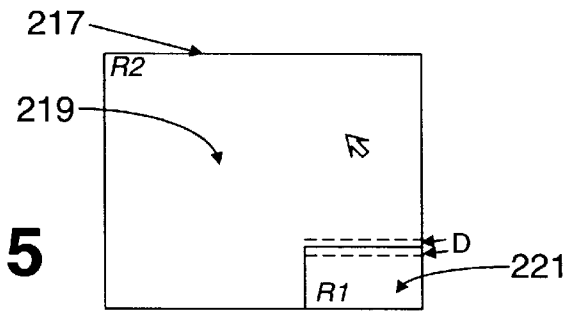

217
R2
219
D
221
R1

FIG. 5

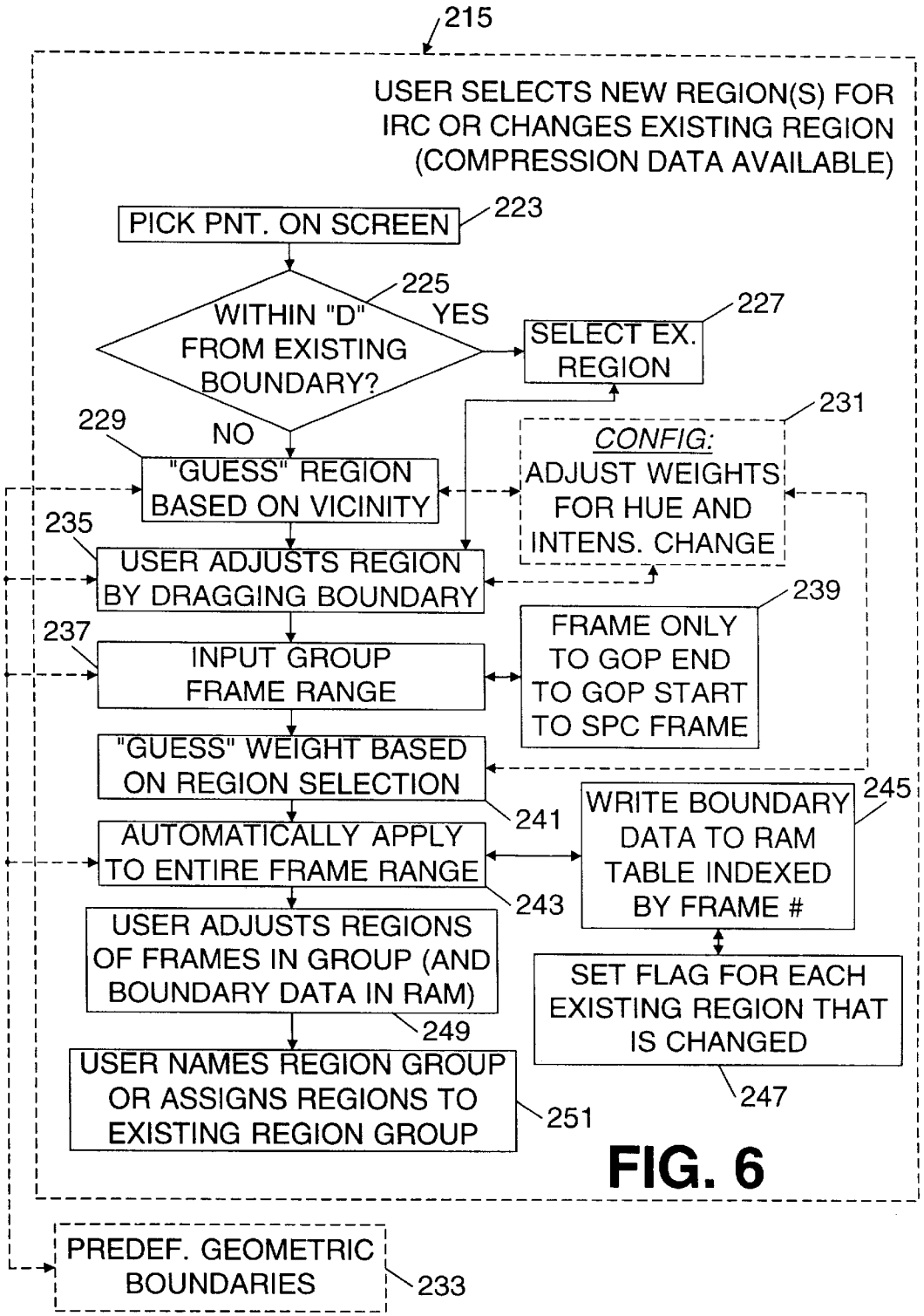

215
USER SELECTS NEW REGION(S) FOR IRC OR CHANGES EXISTING REGION (COMPRESSION DATA AVAILABLE)
PICK PNT. ON SCREEN
223
WITHIN "D" FROM EXISTING BOUNDARY?
225
YES
SELECT EX. REGION
227
NO
229
"GUESS" REGION BASED ON VICINITY
CONFIG: ADJUST WEIGHTS FOR HUE AND INTENS. CHANGE
231
235
USER ADJUSTS REGION BY DRAGGING BOUNDARY
237
INPUT GROUP FRAME RANGE
FRAME ONLY TO GOP END TO GOP START TO SPC FRAME
239
"GUESS" WEIGHT BASED ON REGION SELECTION
241
AUTOMATICALLY APPLY TO ENTIRE FRAME RANGE
243
WRITE BOUNDARY DATA TO RAM TABLE INDEXED BY FRAME #
245
USER ADJUSTS REGIONS OF FRAMES IN GROUP (AND BOUNDARY DATA IN RAM)
249
SET FLAG FOR EACH EXISTING REGION THAT IS CHANGED
247
USER NAMES REGION GROUP OR ASSIGNS REGIONS TO EXISTING REGION GROUP
251
PREDEF. GEOMETRIC BOUNDARIES
233

FIG. 6

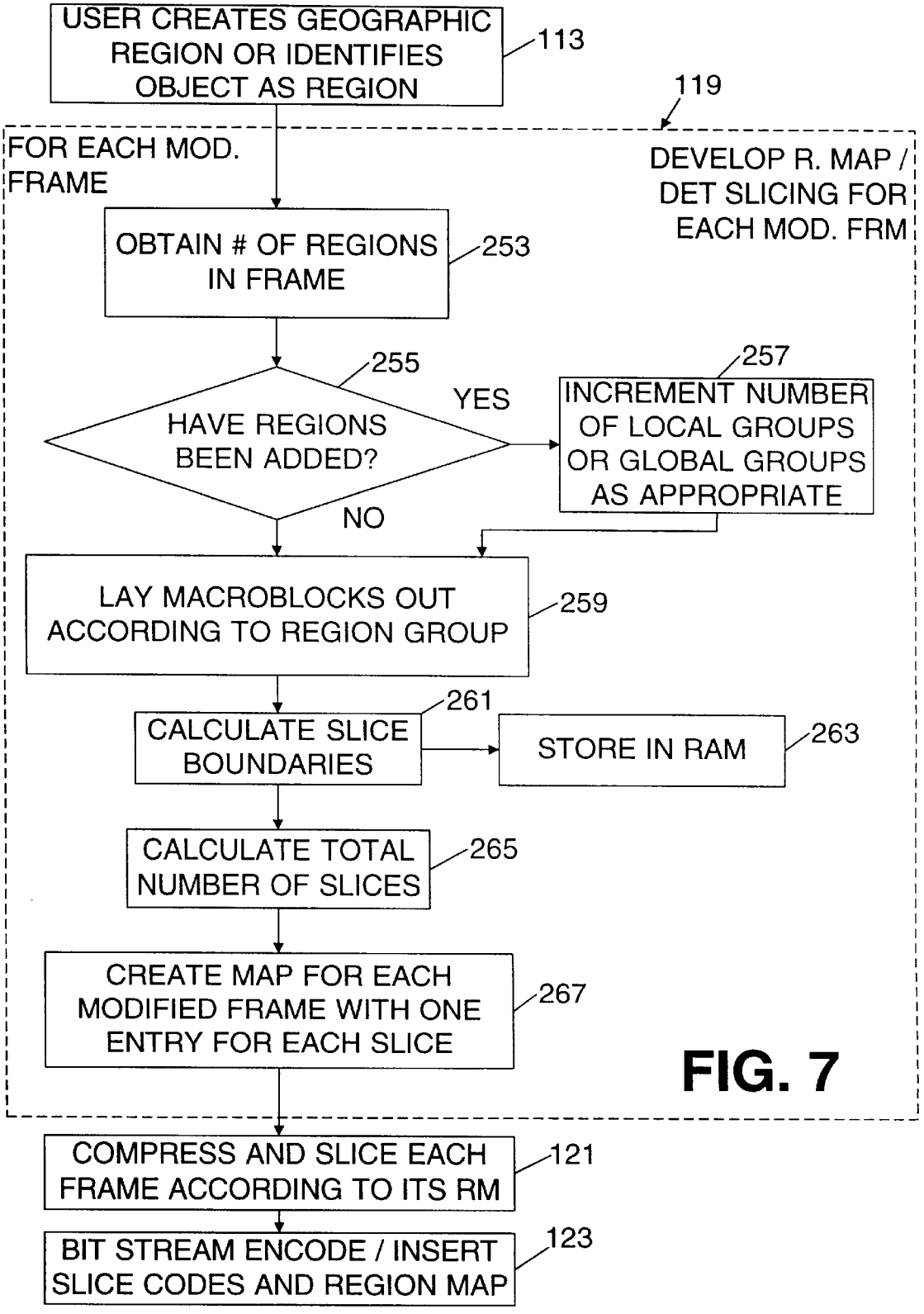
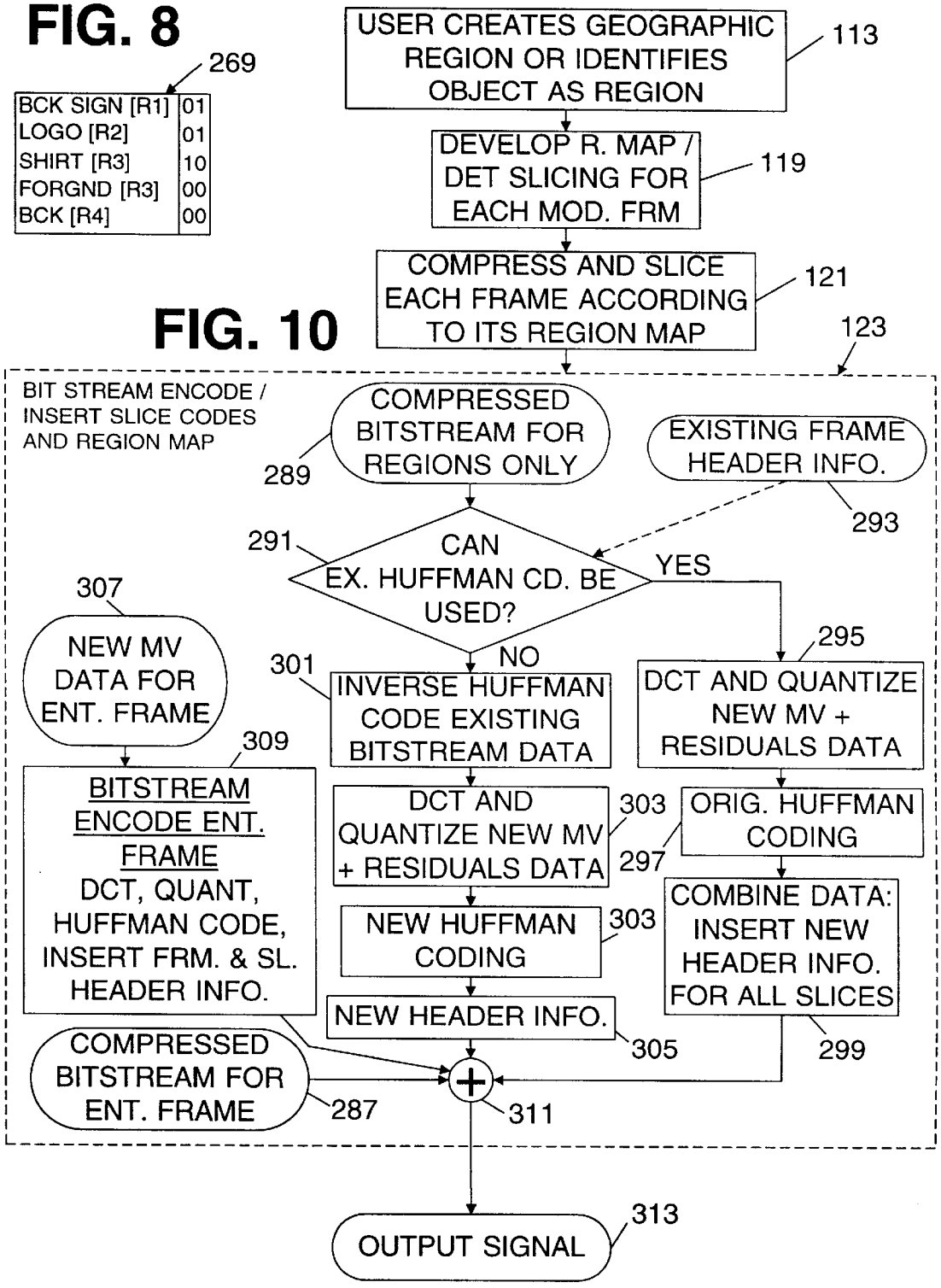

USER CREATES GEOGRAPHIC REGION OR IDENTIFIES OBJECT AS REGION
113
119
FOR EACH MOD. FRAME
DEVELOP R. MAP / DET SLICING FOR EACH MOD. FRM
OBTAIN # OF REGIONS IN FRAME
253
255
HAVE REGIONS BEEN ADDED?
YES
NO
257
INCREMENT NUMBER OF LOCAL GROUPS OR GLOBAL GROUPS AS APPROPRIATE
LAY MACROBLOCKS OUT ACCORDING TO REGION GROUP
259
261
CALCULATE SLICE BOUNDARIES
STORE IN RAM
263
CALCULATE TOTAL NUMBER OF SLICES
265
CREATE MAP FOR EACH MODIFIED FRAME WITH ONE ENTRY FOR EACH SLICE
267
COMPRESS AND SLICE EACH FRAME ACCORDING TO ITS RM
121
BIT STREAM ENCODE / INSERT SLICE CODES AND REGION MAP
123

FIG. 7

FIG. 8

269
BCK SIGN [R1] 01
LOGO [R2] 01
SHIRT [R3] 10
FORGND [R3] 00
BCK [R4] 00

FIG. 10


USER CREATES GEOGRAPHIC REGION OR IDENTIFIES OBJECT AS REGION
113
DEVELOP R. MAP / DET SLICING FOR EACH MOD. FRM
119
COMPRESS AND SLICE EACH FRAME ACCORDING TO ITS REGION MAP
121
123
BIT STREAM ENCODE / INSERT SLICE CODES AND REGION MAP
COMPRESSED BITSTREAM FOR REGIONS ONLY
289
EXISTING FRAME HEADER INFO.
293
291
CAN EX. HUFFMAN CD. BE USED?
YES
NO
307
NEW MV DATA FOR ENT. FRAME
309
BITSTREAM ENCODE ENT. FRAME
DCT, QUANT, HUFFMAN CODE, INSERT FRM. & SL. HEADER INFO.
301
INVERSE HUFFMAN CODE EXISTING BITSTREAM DATA
DCT AND QUANTIZE NEW MV + RESIDUALS DATA
303
295
DCT AND QUANTIZE NEW MV + RESIDUALS DATA
ORIG. HUFFMAN CODING
297
NEW HUFFMAN CODING
303
COMBINE DATA: INSERT NEW HEADER INFO. FOR ALL SLICES
NEW HEADER INFO.
305
299
COMPRESSED BITSTREAM FOR ENT. FRAME
287
311
OUTPUT SIGNAL
313

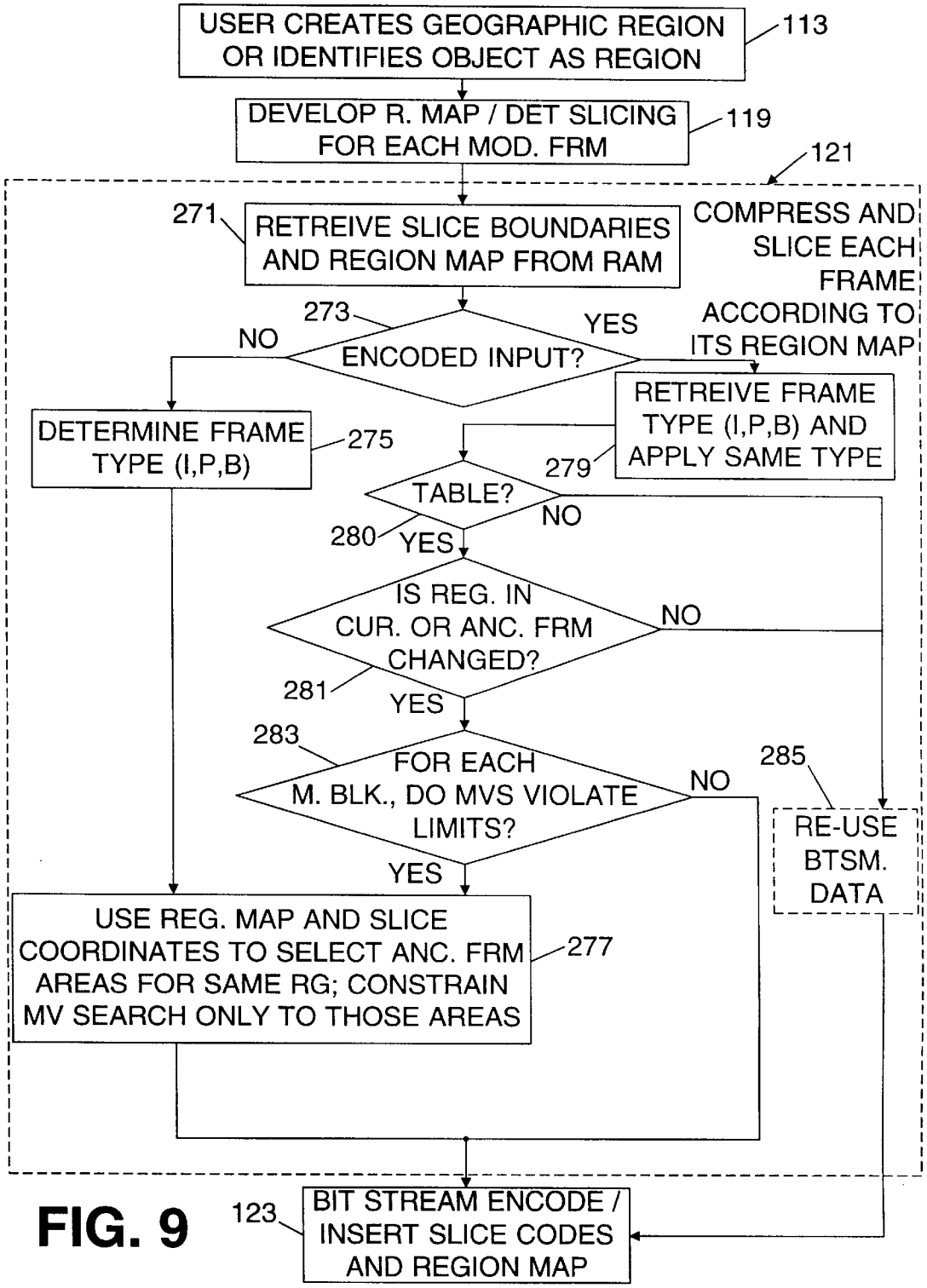

USER CREATES GEOGRAPHIC REGION OR IDENTIFIES OBJECT AS REGION
113
DEVELOP R. MAP / DET SLICING FOR EACH MOD. FRM
119
121
271
RETREIVE SLICE BOUNDARIES AND REGION MAP FROM RAM
COMPRESS AND SLICE EACH FRAME ACCORDING TO ITS REGION MAP
273
ENCODED INPUT?
YES
NO
RETREIVE FRAME TYPE (I,P,B) AND APPLY SAME TYPE
279
DETERMINE FRAME TYPE (I,P,B)
275
TABLE?
NO
280
YES
IS REG. IN CUR. OR ANC. FRM CHANGED?
NO
281
YES
283
FOR EACH M. BLK., DO MVS VIOLATE LIMITS?
NO
285
RE-USE BTSM. DATA
YES
USE REG. MAP AND SLICE COORDINATES TO SELECT ANC. FRM AREAS FOR SAME RG; CONSTRAIN MV SEARCH ONLY TO THOSE AREAS
277
123
BIT STREAM ENCODE / INSERT SLICE CODES AND REGION MAP

FIG. 9

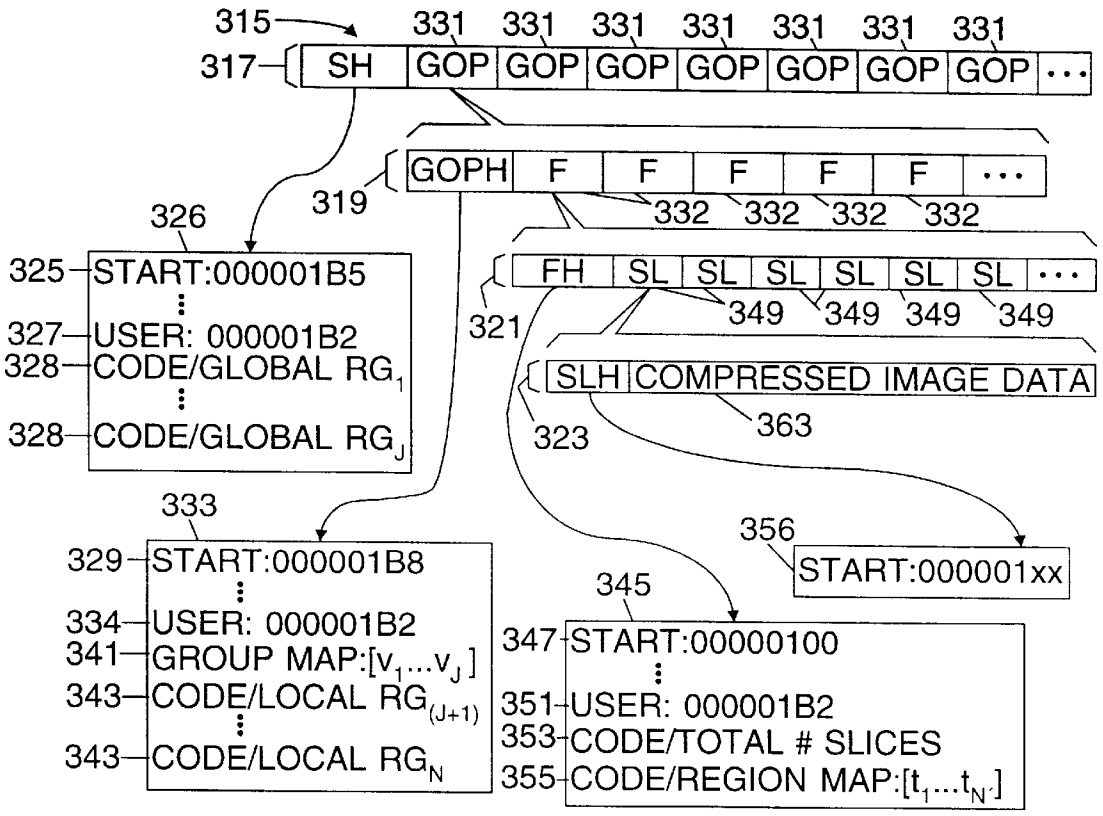


FIG. 11

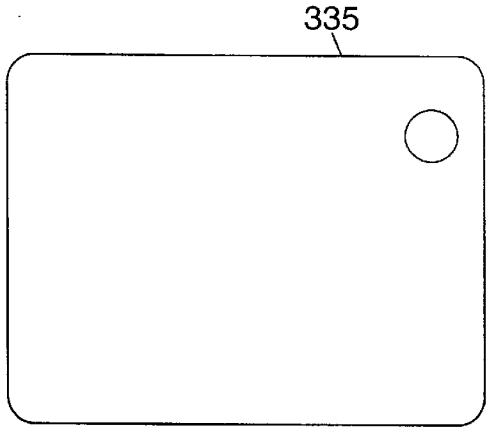


FIG. 12

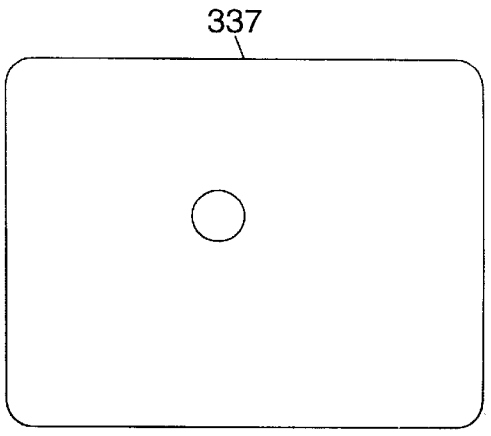


FIG. 13

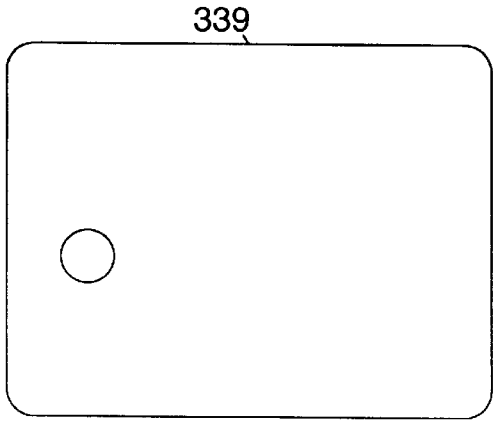


FIG. 14

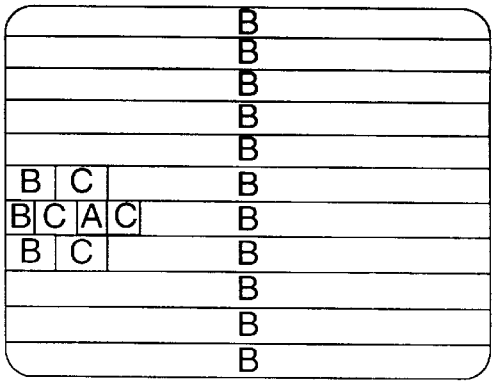


FIG. 15

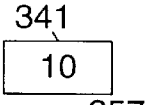


FIG. 16

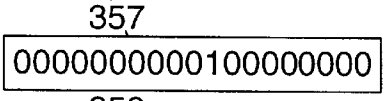


FIG. 17

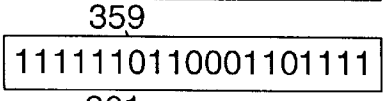


FIG. 18

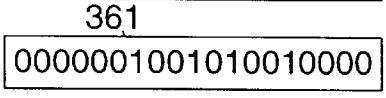


FIG. 19

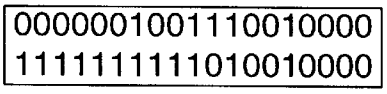


FIG. 20

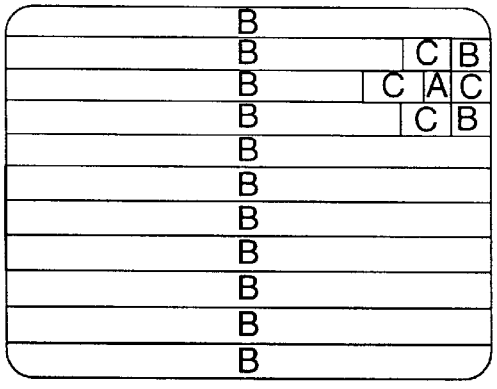
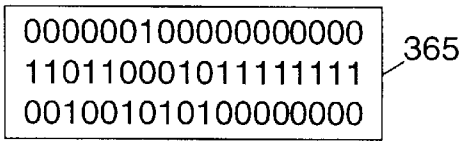


FIG. 21

FIG. 22



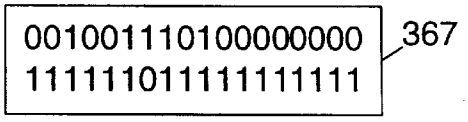


FIG. 23

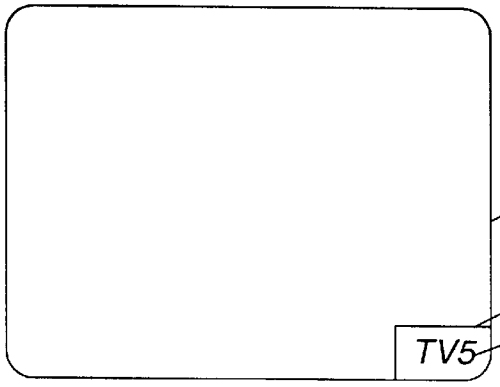

369
371
TV5
373

FIG. 24

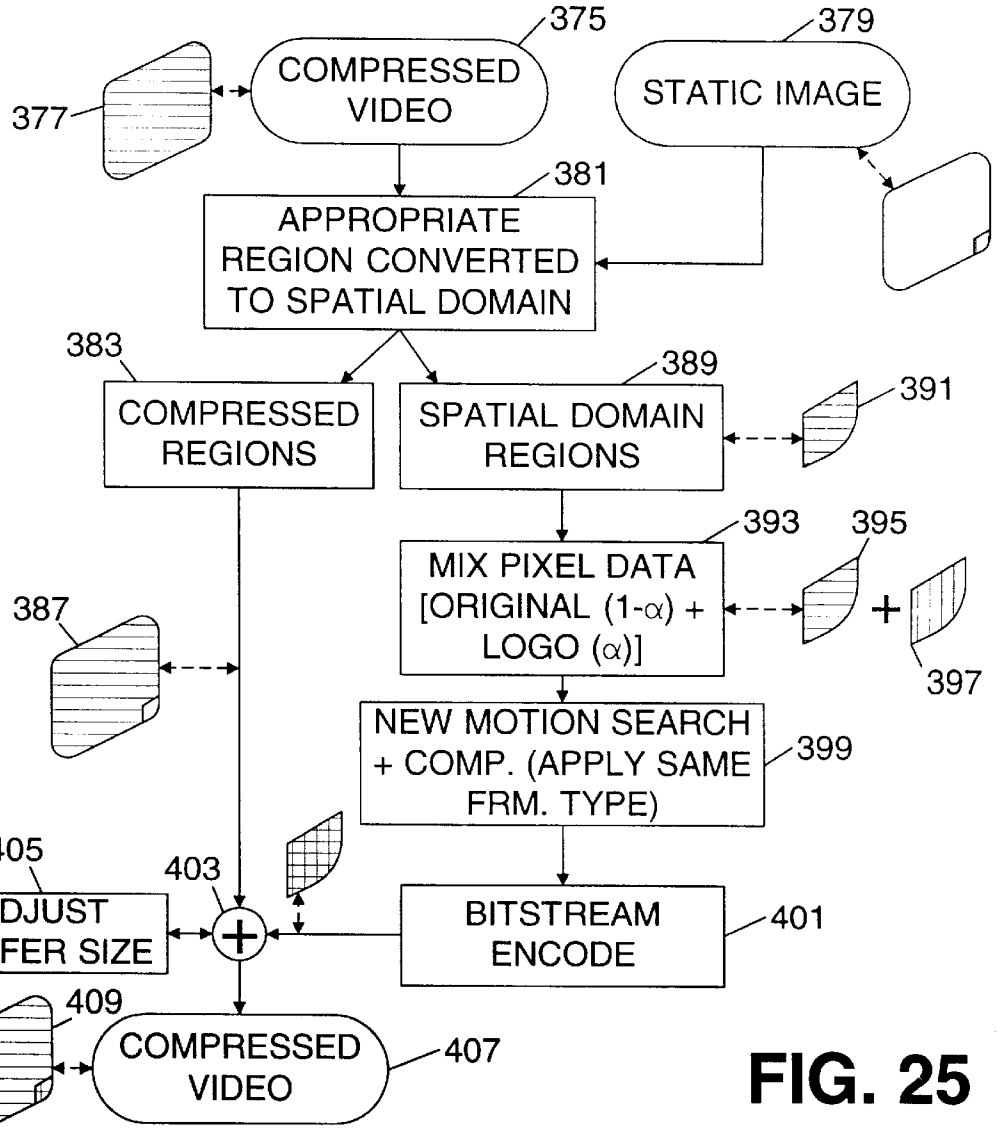

375
COMPRESSED VIDEO
377
379
STATIC IMAGE
381
APPROPRIATE REGION CONVERTED TO SPATIAL DOMAIN
383
COMPRESSED REGIONS
389
SPATIAL DOMAIN REGIONS
391
393
395
MIX PIXEL DATA [ORIGINAL (1-α) + LOGO (α)]
387
397
NEW MOTION SEARCH + COMP. (APPLY SAME FRM. TYPE)
399
405
403
ADJUST BUFFER SIZE
BITSTREAM ENCODE
401
409
COMPRESSED VIDEO
407

FIG. 25

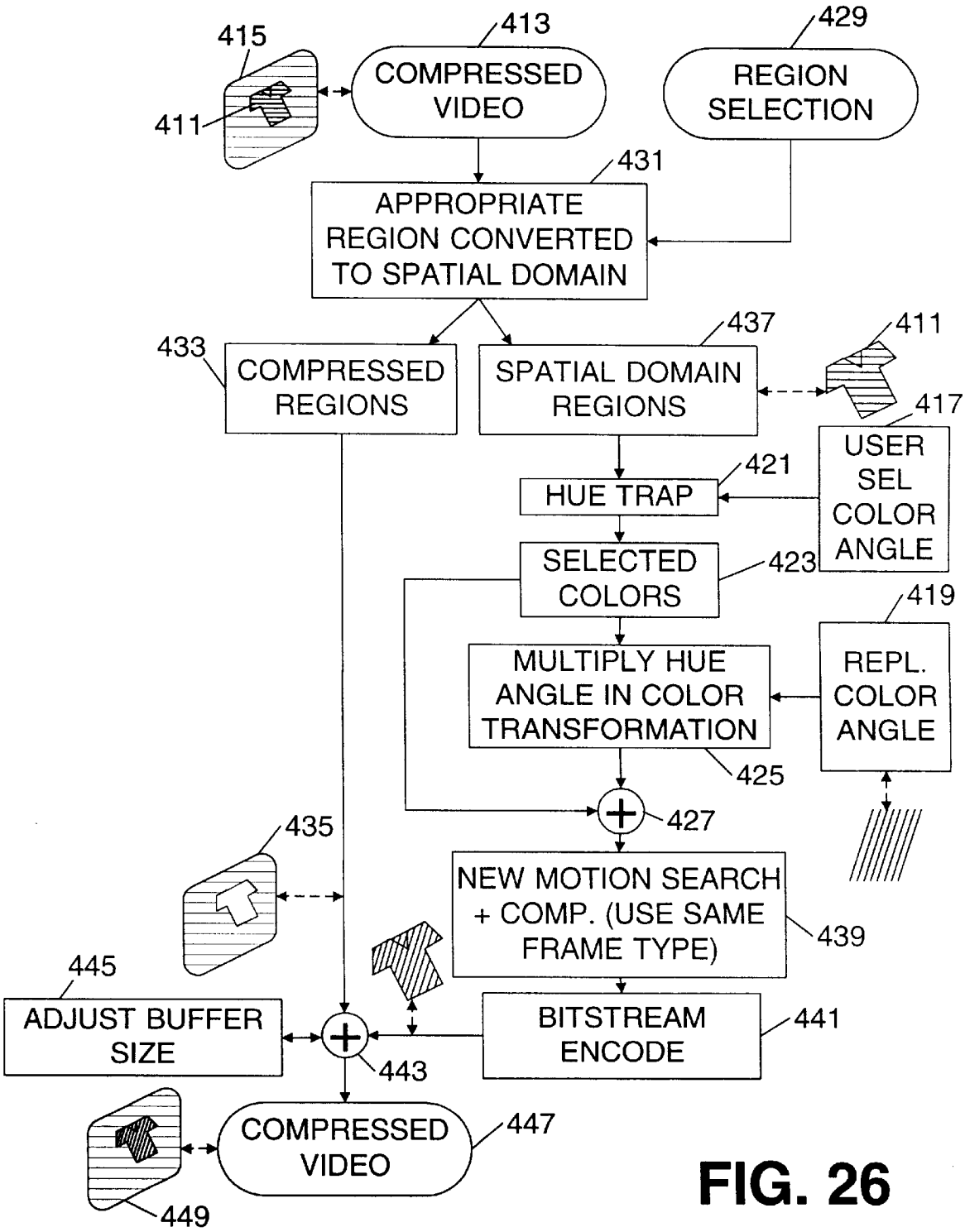

415
413
429
411
COMPRESSED VIDEO
REGION SELECTION
431
APPROPRIATE REGION CONVERTED TO SPATIAL DOMAIN
433
COMPRESSED REGIONS
437
SPATIAL DOMAIN REGIONS
411
417
USER SEL COLOR ANGLE
421
HUE TRAP
SELECTED COLORS
423
419
MULTIPLY HUE ANGLE IN COLOR TRANSFORMATION
REPL. COLOR ANGLE
425
427
435
NEW MOTION SEARCH + COMP. (USE SAME FRAME TYPE)
439
445
ADJUST BUFFER SIZE
BITSTREAM ENCODE
441
443
COMPRESSED VIDEO
447
449

FIG. 26

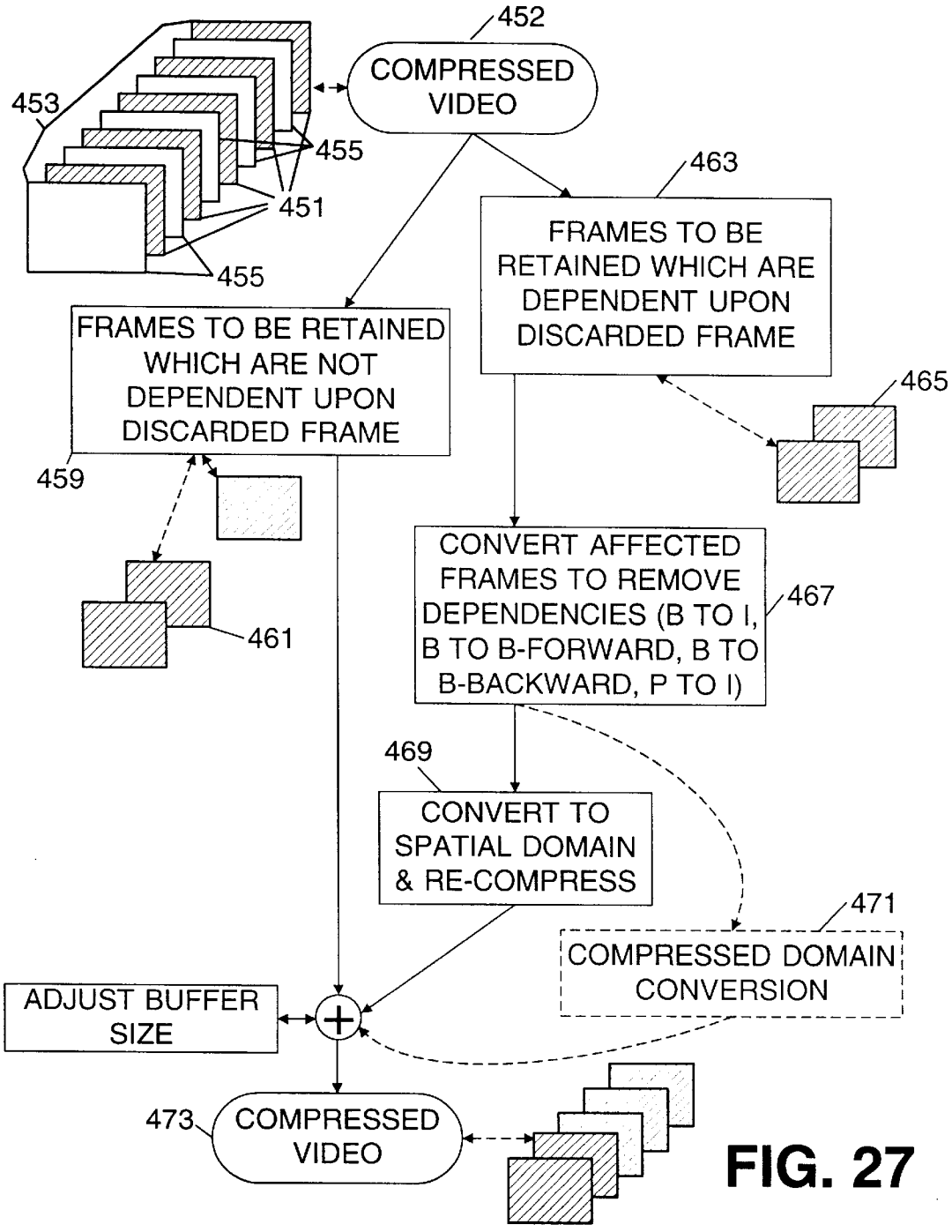

452
COMPRESSED VIDEO
453
455
451
455
463
FRAMES TO BE RETAINED WHICH ARE DEPENDENT UPON DISCARDED FRAME
465
FRAMES TO BE RETAINED WHICH ARE NOT DEPENDENT UPON DISCARDED FRAME
459
461
CONVERT AFFECTED FRAMES TO REMOVE DEPENDENCIES (B TO I, B TO B-FORWARD, B TO B-BACKWARD, P TO I)
467
469
CONVERT TO SPATIAL DOMAIN & RE-COMPRESS
471
COMPRESSED DOMAIN CONVERSION
ADJUST BUFFER SIZE
473
COMPRESSED VIDEO

FIG. 27

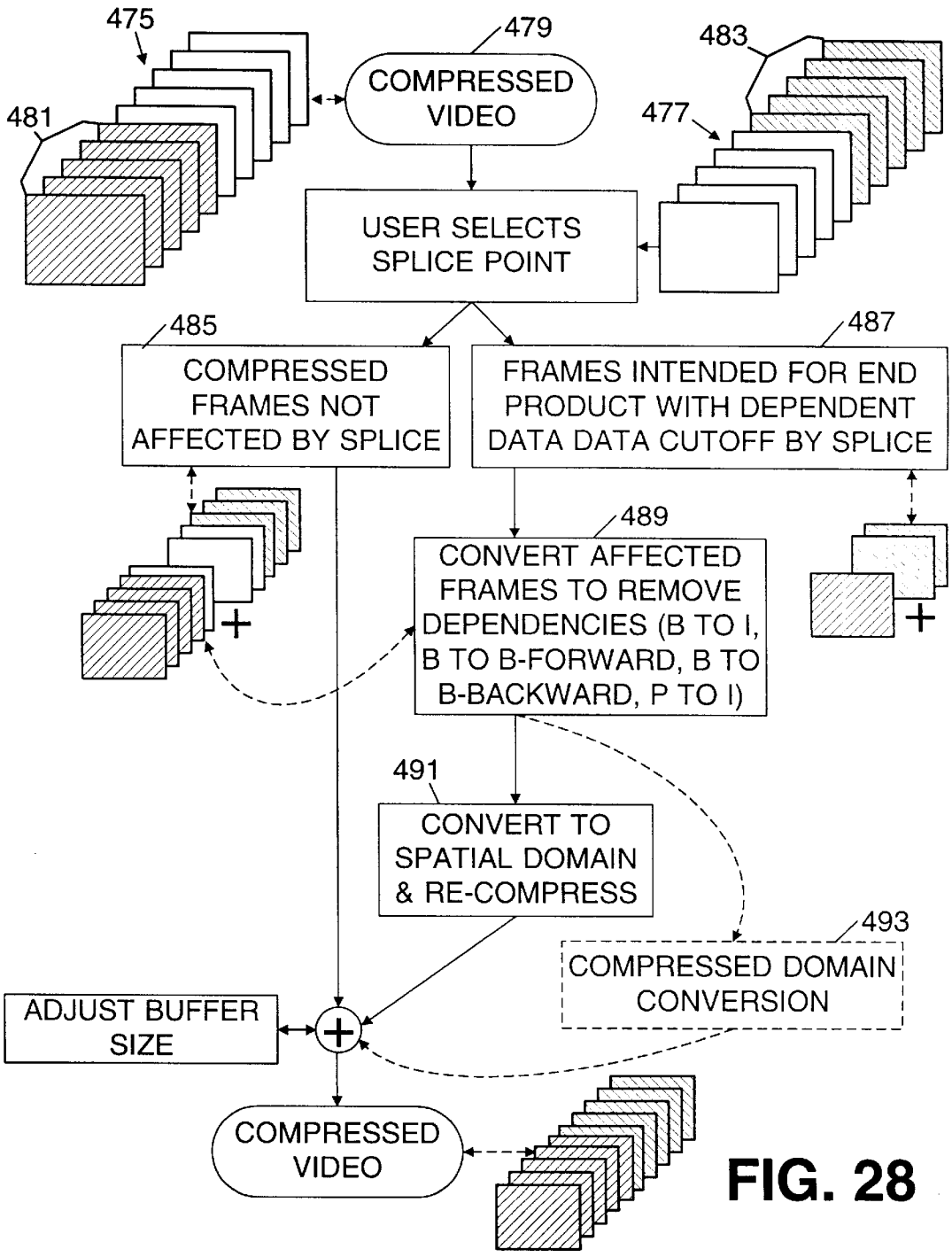

475
481
479
COMPRESSED VIDEO
483
477
USER SELECTS SPLICE POINT
485
COMPRESSED FRAMES NOT AFFECTED BY SPLICE
487
FRAMES INTENDED FOR END PRODUCT WITH DEPENDENT DATA DATA CUTOFF BY SPLICE
489
CONVERT AFFECTED FRAMES TO REMOVE DEPENDENCIES (B TO I, B TO B-FORWARD, B TO B-BACKWARD, P TO I)
491
CONVERT TO SPATIAL DOMAIN & RE-COMPRESS
493
COMPRESSED DOMAIN CONVERSION
ADJUST BUFFER SIZE
COMPRESSED VIDEO

FIG. 28

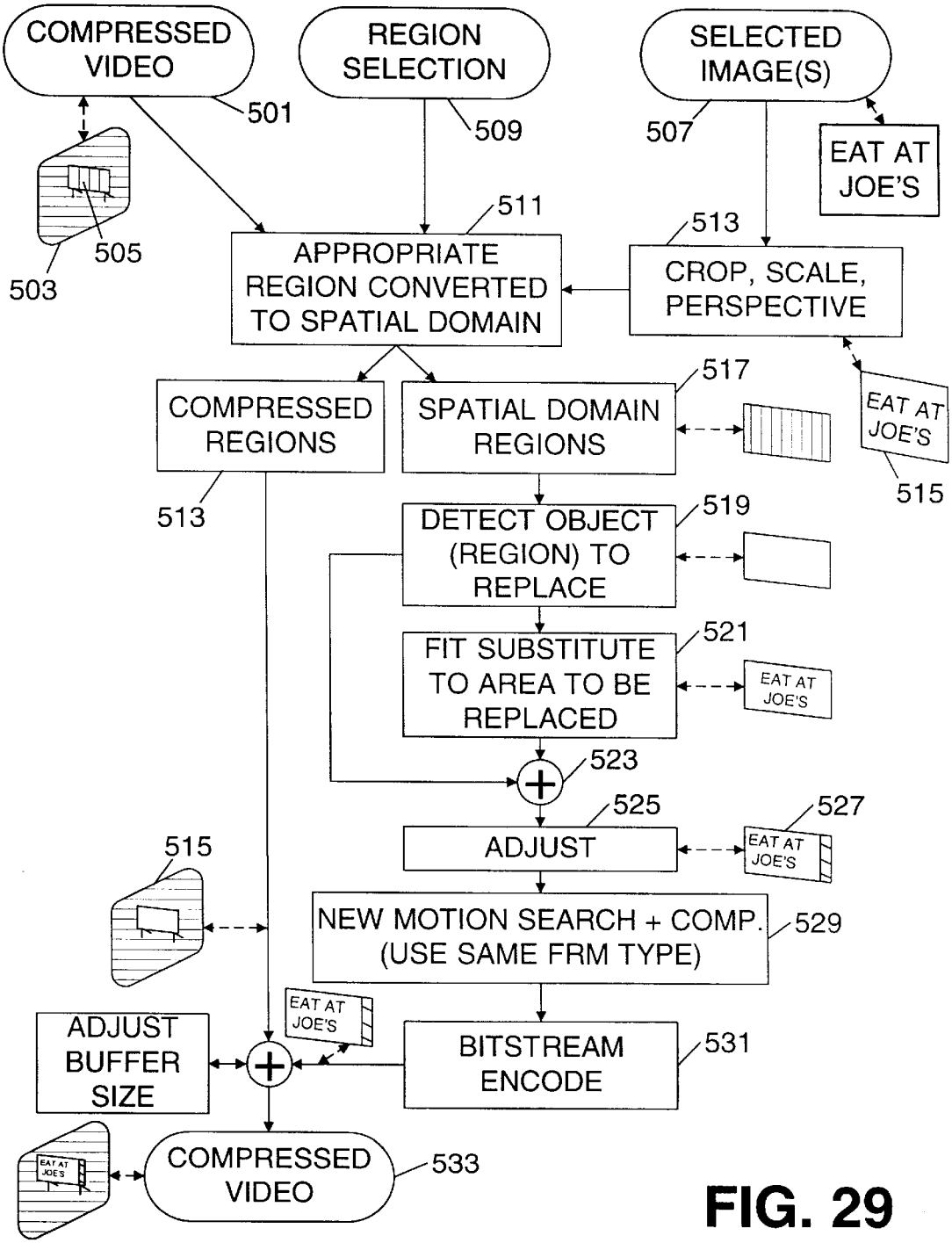

COMPRESSED VIDEO
501
REGION SELECTION
509
SELECTED IMAGE(S)
507
EAT AT JOE'S
503
505
511
APPROPRIATE REGION CONVERTED TO SPATIAL DOMAIN
513
CROP, SCALE, PERSPECTIVE
COMPRESSED REGIONS
513
SPATIAL DOMAIN REGIONS
517
EAT AT JOE'S
515
DETECT OBJECT (REGION) TO REPLACE
519
FIT SUBSTITUTE TO AREA TO BE REPLACED
521
EAT AT JOE'S
523
525
ADJUST
527
EAT AT JOE'S
515
NEW MOTION SEARCH + COMP. (USE SAME FRM TYPE)
529
EAT AT JOE'S
ADJUST BUFFER SIZE
BITSTREAM ENCODE
531
EAT AT JOE'S
COMPRESSED VIDEO
533

FIG. 29

IMAGE SEQUENCE COMPRESSION FEATURING INDEPENDENTLY CODED REGIONS

The present invention relates to image sequence compression. More particularly, this disclosure provides a compression system that utilizes independently coded regions to permit select extraction of image objects, or editing of select areas of an image frame, without necessarily decompressing all image data in each frame. This disclosure also provides a mechanism of tracking the objects and regions across multiple frames such that, if desired, they may be independently coded and extracted from a video sequence.

BACKGROUND

Conventional editing or other processing of film or video images is performed in the "spatial" domain, that is, upon actual images rather than upon a compressed representation of those images. Since the final product of such editing or processing is frequently an uncompressed signal (such as a typical "NTSC" television signal), such editing or processing can sometimes with today's digital editors and computers be accomplished in real-time. With increasing tendency toward high resolution pictures such as high definition television ("HDTV"), however, Internet, cable, television network and other service providers will likely all have to begin directly providing compressed signals as the final product of editing. As used herein, the term "video" will refer to any electronic signal that represents a moving picture sequence, whether digital, NTSC, or another format.

One problem relating to the new digital standards relates to efficiently and quickly processing video; with video stored or transmitted in compressed format under the new standards, it is difficult computationally to decompress video, process that video in the spatial domain, and then recompress output video. Examples of processing compressed video prior to display include providing fast forward, reverse and other effects typically associated with VCRs. Other processing examples associated with the production or broadcast of video include color correction, logo insertion, blue matting, and other conventional processes.

To take one example of this computational difficulty, in logo insertion, a local television station might receive a compressed satellite feed, insert its own TV station logo in a corner of the image that will be seen on viewers' TV sets, and then broadcast a TV signal over cable, back over satellite or through the airwaves. Conventionally, the processing could be performed in real time or with a short delay, because it is relatively easy to decompress an image, modify that image in the spatial domain and transmit a spatial domain signal (e.g., an uncompressed NTSC signal). With HDTV and other new digital standards, which call for all transmissions in a compressed format, this quick processing becomes much more difficult, since it is very computationally expensive to compress a video signal.

All of the video examples given above, e.g., logo insertion, color correction, fast forward, reverse, blue matting, and similar types of editing and processing procedures, will collectively be referred to interchangeably as "editing" or "processing" in this disclosure. "Fast forward" and similar features commonly associated with a video cassette recorder ("VCR") are referred to in this manner, because it may be desired to change the sequence or display rate of frames (thereby modifying an original video signal) and output a new, compressed output signal that includes these changes. The compressed output signal will often require that frames be re-ordered and re-encoded in a different format (e.g., to depend upon different frames), and therefore is regarded as one type of "editing."

In most of the examples given, since editing or processing is typically done entirely in the spatial domain, a video signal must typically be entirely decompressed to the spatial domain, and then recompressed. These operations are typically required even if only a small part of an image frame (or group of frames) is being edited. For example, taking the case of logo insertion in the bottom right corner of an image frame, it is extremely difficult to determine which part of a compressed bit stream represents a frame's bottom right corner and, consequently, each frame of the video sequence is typically entirely decompressed and edited. If it is desired to form a compressed output signal, frames of the edited signal must then typically be compressed anew.

In this regard, many compression formats are based upon "motion estimation" and "motion compensation." In these compression formats, blocks or objects in a "current" frame are recreated from similar blocks or objects in one or two "anchor" frames; "motion estimation" refers to a part of the encoding process where a computer for each block or object of a current frame searches for a similar image pattern within a fairly large area of each anchor frame, and determines a closest match within this area. The result of this process is a motion vector which usually describes the relative position of the closest match in an anchor frame. "Motion compensation" refers to another part of the encoding process, where differences between each block or object and its closest match are taken, and these differences (which are ideally all zeros if the match is "good") are then encoded in some compact fashion, often using a discrete cosine transform ("DCT"). These processes simply imply that each portion of the current frame can be almost exactly reconstructed using the location of a similar looking portion of the anchor frame as well as difference values. Not every frame in a sequence is compressed in this manner.

Motion estimation is very computationally expensive. For example, in applying the MPEG-2 standard, a system typically takes each block of 8×8 pixels and searches for a closest match within a 15×15 pixel search window, centered about the expected location for the closest match; such a search involves 64 comparisons to find the closest match, and each comparison in turn requires 64 separate subtractions of multi-bit intensity values. When it is considered that a typical image frame can have thousands of 8×8 pixel blocks, and that this searching is typically performed for the majority of frames in a video sequence, it becomes quite apparent that motion estimation is a computationally expensive task.

With the expected migration to digital video and more compact compressed transmission formats, it is apparent that a definite need exists for quick compression systems and for systems which provide quick editing ability. Ideally, such a system should permit decoding and editing of a compressed signal (e.g., VCR functions, logo insertion, etcetera) yet permit real-time construction and output of compressed, edited video signal that can be accepted by HDTV and other new digital systems. Ideally, such a system would operate in a manner compatible with existing object-based and block-based standards and desired editing procedures, e.g., such that it can specially handle a logo to be inserted into a compressed signal, as well as other forms of editing and processing. Further still, such a system ideally should be implemented as much as possible in software, so as to be compatible with existing computers and other machines which process video. The present invention satisfies these needs and provides further, related advantages.

SUMMARY

The present invention solves the aforementioned needs by providing a system having independently coded regions. Using these regions, one may specially compress and encode a data sequence in a manner that permits extraction or editing of select objects in the spatial domain, without need to decode and decompress entire sequences. If it is desired to modify a compressed output signal to include modified data for an object (e.g., for an edited object), new data can be inserted as appropriate in the place of the extracted object; with the object being independently coded, all other compressed data for the sequence (e.g., background or other specific objects) may be exactly re-used. In real time applications, this ability facilitates editing and production of a compressed output signal using standard computer and editing equipment. As can be seen therefore, the present invention should have ready application to production, post production, network syndication, Internet, and other applications which call for the production of compressed video, audio and other signals.

The invention provides an apparatus that produces a signal representing multiple compressed data frames. The apparatus may be applied to audio or video data, or any other type of data that is suitable for storage or transmission as a sequence of related data frames. In the preferred embodiment, this form of the invention is applied to compressed video frames to generate independently coded regions as part of an output video sequence. The preferred embodiment may be applied by a network or video production house to generate an image sequence in compressed format (e.g., satellite transmission, DVD program, video tape or other program) in a manner optimized for quick or real-time editing. To take a few examples, with a compressed image sequence already processed to have independently coded regions, a local television station may insert logos and a post production house may provide color correction without completely decompressing and processing the entire image sequence, i.e., by processing only one or a small number of independently coded regions. Alternatively, the preferred embodiment may also be implemented in a digital VCR or by a local television station; by performing minor editing or processing (e.g., signal mixing, frame re-ordering for fast forward, logo insertion, etc.) without having to completely re-encode an entire video sequence, these entities may more easily generate a digital (HDTV) output signal in real-time or close to real-time.

According to a first form of the invention, a compression system encodes at least one data frame as an anchor frame and at least one other data frame in dependent format, such that each dependent frame may be recreated from one or two anchor frames. This form of the invention calls for identifying at least two data sets (appearing across multiple image frames) that are to be compressed independently of one another, and also for constraining motion search and compensation such that motion vectors for each data set in a dependent frame may only point to the same data set in one or two anchor frames. "Data sets" can refer to an object that appears in multiple frames (the object can vary in shape size, color, intensity, etc.), as well as a static shape and position (e.g., each screen's lower right-hand corner, irrespective of image content).

In a second form of the invention, there will be at least two frames, one of which is to be compressed as a dependent frame, and another of which is to be compressed as an anchor frame. Typically, the dependent frame is recreated by first decompressing the anchor frame to generate spatial domain data and, second, taking motion vectors and residuals associated with the dependent frame and "building" the dependent frame's content using "pieces" of the already-decompressed anchor frame. This form of the invention calls for generating a compressed output signal by providing a user with ability to designate spatial domain data in a dependent frame, by automatically associating data from another, anchor frame with that data, and by compressing an output sequence in a manner such that the dependent frame is compressed into motion vector-plus-residual format, with all motion vector dependency of the dependent frame constrained to only point to associated data of an anchor frame.

Other forms of the invention are set forth by the claims below, including various methods, apparatuses and improvements. In more particular aspects, these forms of the invention may be implemented as video or audio encoders, transcoders and editing devices.

The invention may be better understood by referring to the following detailed description, which should be read in conjunction with the accompanying drawings. The detailed description of a particular preferred embodiment, set out below to enable one to build and use one particular implementation of the invention, is not intended to limit the enumerated claims, but to serve as a particular example thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1–10** illustrate the arrangement and operation of an encoder/transcoder that implements principles of the present invention.

FIG. **1** indicates primary functions of the encoder/transcoder.

FIG. **2** is a component level diagram, showing how software implementing the preferred embodiment is implemented to process an input video signal and to generate an output video signal.

FIG. **3** is a flow diagram showing M.P.E.G.-2 compression in the context of independently coded regions.

FIG. **4** is an expanded flow diagram, and indicates further functions performed within block **113** of FIG. **1**.

FIG. **5** is an illustration of a visual display where existing regions are highlighted to a user who will modify existing regions, frame order, or add new regions.

FIG. **6** is an expanded flow diagram, and indicates further functions performed within block **215** of FIG. **4**.

FIG. **7** is an expanded flow diagram, and indicates further functions performed within block **119** of FIG. **1**.

FIG. **8** is an illustration of a table that may be used for each frame to track edits, a "registry of edits" as it will be labeled further below.

FIG. **9** is an expanded flow diagram, and indicates further functions performed within block **121** of FIG. **1**.

FIG. **10** is an expanded flow diagram, and indicates further functions performed within block **123** of FIG. **1**.

FIGS. **11–24** are used to explain a signal format for a video sequence, where the signal itself includes information sufficient to identify an object or frame location that has been independently coded, and to identify which image slices in a sequence permit decoding of the object of interest.

FIG. **11** illustrates the hierarchy of a basic MPEG format signal, including a video sequence having many groups of pictures (GOPs). Each GOP includes multiple frames, each frame includes multiple slices, and each slice includes compressed image data. FIG. **11** also shows bit stream codes

for header information, for each of sequence, GOP, frame and slice level tiers. FIG. **11** further shows how region group definition and region map information are inserted into this preferred signal format.

FIGS. **12–14** illustrate a group of three image frames, where a ball appears to move from right to left across these frames.

FIG. **12** shows the ball at the upper right hand corner of a first image frame.

FIG. **13** shows the ball in the middle of a second image frame.

FIG. **14** shows the ball at the left side of a third image frame.

FIG. **15** corresponds to the third image frame (FIG. **14**) and illustrates one methodology for how regions might be created and sliced in a MPEG-2 format, where region "A" corresponds to ball only, region "B" corresponds to a blue sky background, and region "C" corresponds to "boundary" areas having both ball and background. The rectangles of FIG. **15** represent nineteen image slices and are labeled "A," "B" or "C" only for purposes of illustrating whether the slice contains data belonging to these regions. Importantly, the preferred MPEG-2 format usually requires a new image slice for each new line of macro-blocks such that in practice a great many more slices would be indicated than nineteen slices seen in FIG. **15**, which is used for illustration and explanation only.

FIG. **16** shows a hypothetical group map where two globally defined region groups have been defined for the sequence (a ball and a child) and a one bit entry is provided for each globally defined region group to indicate whether it is present in the GOP of FIGS. **12–14**. [Otherwise stated, FIGS. **12–14** include the image of a ball but not of a child, which presumably appears elsewhere in the image sequence; thus, the bit entries are "1" (signifying that the ball is present in this GOP) and a "**0**" (signifying that the child is not present in this GOP).]

FIGS. **17–19** show a first region mapping scheme, corresponding to the third frame of FIGS. **14** and **15**. Each of FIGS. **17–19** show a different one of three tables of the region map.

FIG. **17** shows a first table for region "A" of FIG. **15**. The table has nineteen entries, one for each image slice seen in FIG. **15**. Each entry indicates whether image data for the region "A" is found in the corresponding image slice.

FIG. **18** is similar to FIG. **17**, except it shows the table for region "B" of FIG. **15**.

FIG. **19** is similar to FIG. **17**, except it shows the table for region "C" of FIG. **15**.

FIG. **20** presents a second region mapping scheme. Instead of separately identifying transition regions for both ball and background (as was illustrated by FIGS. **15** and **17–20**), only two tables are used. In the first row of FIG. **20** (i.e., a first table), values represent whether a corresponding image slice has any ball data (whether or not background data is also present). A second row (i.e., second table) indicates whether a corresponding image slice has any background data (whether or not ball data is also present). One difference between the two mapping schemes is that the second mapping scheme, represented by FIG. **20**, allows an image slice to be associated with two different regions. The mapping scheme of FIG. **20** is preferred especially when many regions are to be used (and, thus, where it might be cumbersome to have separate regions dedicated to each boundary between objects).

FIG. **21** is similar to FIG. **15**, except that FIG. **21** shows the first mentioned mapping scheme for the first frame of FIG. **12**. As can be seen from FIG. **21**, its image data represents the position of the ball in the upper right hand corner of the first image frame; FIG. **21** defines eighteen image slices instead of the nineteen image slices of FIG. **15**.

FIG. **22** illustrates the first mapping scheme applied to the example of FIG. **21**. In particular, FIG. **22** illustrates the entire region map including three tables, one for each of regions "A," "B" and "C" of FIG. **21**, each having eighteen data values corresponding to eighteen image slices.

FIG. **23** illustrates the second mapping scheme applied to the example of FIG. **21**. In particular, FIG. **23** illustrates the entire region map including two tables, one for each image slice having ball data (i.e., regions labeled "A" or "C") and one for each image slice having background data (i.e., regions labeled "B" or

FIG. **24** is a hypothetical image frame showing a local television station logo "TV**5**" which has been inserted in the bottom right hand corner of the image frame. FIG. **24** is used to explain creation of a globally defined region group corresponding to the bottom right hand corner of each image frame. Such a global region group is defined in logo insertion applications, such that a corner of each frame is inherently independently coded for ready logo insertion, without complete decoding and decompression of the entirety of each image frame in a video sequence.

FIGS. **25–29** are used to describe several editing applications facilitated by the use of independently coded regions.

FIG. **25** provides a flow diagram for logo insertion; in connection with FIG. **25**, it is presumed that a compressed video signal input already has an independently coded region at the bottom right hand corner of each image frame.

FIG. **26** presents a flow diagram for color correction; in connection with FIG. **26**, it is presumed that one wishes to change the color of an actor's shirt, where the shirt or the actor have already been independently encoded within a compressed video signal input.

FIG. **27** presents a flow diagram showing one method of fast forward or reverse play.

FIG. **28** presents a flow diagram showing the splicing together of two image sequences.

FIG. **29** presents a flow diagram showing the splicing together of an image sequence with an image, or second image sequence; the image or second image sequence, represented as a billboard close-up featuring the slogan "EAT AT JOE'S" is illustrated as being mixed into an independently coded region of the first image sequence. The processes represented by FIGS. **27** and **28** may be employed in cases of mixing two image sequences together, where the second image sequence is to be inserted into an independently coded region of the first image sequence.

DETAILED DESCRIPTION

The invention summarized above and defined by the enumerated claims may be better understood by referring to the following detailed description, which should be read in conjunction with the accompanying drawings. This detailed description of a particular preferred embodiment, set out below to enable one to build and use one particular implementation of the invention, is not intended to limit the enumerated claims, but to serve as a particular example thereof.

The particular example set out below is a preferred implementation of several components that implement,

facilitate and employ independently coded regions. The invention, however, may also be applied to other types of systems as well.

I. General Introduction.

This disclosure sets forth an encoder, a decoder and several signal formats. Each of these items have a wide variety of applications that will be apparent from the description below.

The encoder takes a data sequence having discrete frames, and compresses those frames for storage or transmission such that "regions" of frames can be independently extracted and decompressed. The frames are subdivided into these regions and then encoded using certain rules, such that they may be decoded with necessary decoding the entirety of every frame in the sequence. The encoder may be used to newly compress a "spatial domain signal" (that is, conventional analog or display-ready input signal) to have independently coded regions ("ICRs"), and it may also be applied in the form of a "transcoder," that is, in a system that receives a compressed input, modifies it in some manner, and then applies an encoder to provide a compressed output signal with ICRs as desired. It is hoped that use of this encoder will make it relatively easy for TV networks, stations, broadcasters, post-production houses and other entities to edit or process a compressed signal and provide a compressed output at or near real-time. For example, use of an encoder or transcoder as mentioned above for satellite signal distribution may render it relatively easy for a downstream TV station to insert its own logo and quickly retransmit a modified signal, through editing only one ICR of interest and re-encoding only the edited portion. If a received signal has been already generated to have these ICRs, then an encoder or transcoder may also be used by the local TV station to facilitate quick editing.

It is hoped that use of these various elements will make it relatively easier to fabricate digital systems in hardware and software that can process signals and provide compressed output signals at or near real-time. The embodiments described below can be applied to audio signals or other information suitable for transmission in a frame type format, but the preferred application is to video, especially HDTV and digital standards that call for transmission or storage in a compressed format. The preferred system described below operates using "MPEG-2 " compression standards (indicating standard no. 2 proposed by the "moving pictures experts group"), but the system can be applied to any compression format, including MPEG-1, MPEG-4, H.261, H.263 and other types of formats. While conventional systems operate on analog television signals (e.g., while a digital video disk ("DVD") player typically provides an analog television signal output), it is expected that with the spread of Internet broadcasting and HDTV especially, more systems will necessarily accept compressed inputs, and one primary application of the present invention is to facilitate video processing systems (such as VCRs and disk players) which provide a processed or edited compressed output signal in real-time. Another primary application of the present invention is to video broadcast systems used in satellite transmission, cable routing, Internet broadcasting, network or TV station editing and similar types of systems where a compressed video signal is a desired output.

Thus, it should be apparent that there are a wide variety of systems to which the elements and techniques described below may be applied, including to home entertainment systems (such as televisions, VCRs, disk players, home routers or servers for video signals), video recording (such as by networks, live sporting events and the like), video processing and editing (such as by networks, post-production houses, studios, TV stations, Internet broadcasters, program distributors and the like) and by local distributors such as TV stations and cable and satellite service providers.

As used in this disclosure, the terms identified below shall have the following meanings.

A "frame" of data shall be interpreted to apply to audio, audiovisual data, and any other type of data that is typically transmitted in multiple, discrete frames.

"Software" includes any stored instructions that electronically control the functions provided by a system, and specifically includes firmware as well as software.

"Video" includes image data that is transmitted or stored electronically as a sequence of image frames, and shall specifically include all television formats, irrespective of frame rate, color modulation schemes and other features which distinguish individual standards. For example, "video" includes formats used for video conference, computer monitor transmission and television formats wherever developed. "Video" specifically includes digital formats (e.g., "DVD" and "HDTV"), differing compression formats (e.g., "MPEG" schemes and "H.261 " and "H.263 ") and different conventional analog television formats (e.g., "NTSC," "PAL" and "SECAM").

An "anchor" frame includes any frame upon which another frame directly depends for reconstruction, and it may be either an independent frame or a dependent frame. As non-limiting examples, in conventional "MPEG" formats, dependent frames may be recreated from independent "I" frames as well as predictive "P" frames (which themselves depend upon other frames for reconstruction); both of these "I" and "P" frames would be anchor frames if another frame uses them for reconstruction.

An "independent" frame includes any frame that does not depend upon another frame for reconstruction, e.g., an independent frame is compressed in a manner where its image content can be completely obtained without decompressing any other frame. In conventional "MPEG" formats, only "I" frames are independent.

A "dependent" frame includes any frame that does depend upon another frame for reconstruction. In conventional "MPEG" formats, a dependent frame can include "P" frames (themselves depending upon either "I" or "P" frames, which are previously decoded) as well as "B" frames (themselves depending upon one or two "I" or "P" frames which are previously decoded). Since "B" frames can depend upon two anchor frames (one of which can be later in the video sequence), the frames are typically stored or transmitted out of order. For example, if three consecutive frames are to be encoded as "I," "B" and "P" frames respectively, these frames would be stored or transmitted in the order "IPB" and would be decoded in this order and then reordered for display.

A "current" frame includes whichever frame is currently being processed. For example, when encoding a dependent frame, the dependent frame is the "current" frame and the corresponding "anchor" frame(s) would be whichever one or two frames is used as a direct reference for compression and reconstruction of the current frame.

"Coding" or "encoding" are used interchangeably, and refer to compression of image frames to a compressed format. The compressed format can be a conventional "IPB" format defined by various "MPEG" standards, a compressed bit stream (e.g., "I," "P" or "B" frames which then are quantized, Huffman coded, etcetera, to simply be a stream of numbers), or another format.

An "independently coded region" or "ICR" includes image data that is coded in a restricted manner, so that a portion of a video sequence may be encoded in dependency upon each other only. As an example, if a "current" image frame is to be encoded as a "P" frame (that depends upon a different "I" frame) and it is desired to encode a set of actors independently from a background image, then an "independently coded region" might be created separately for each of the set of actors and the background. That is to say, each of the "P" frame and the "I" frame could be divided into two regions, and each region (e.g., the set of actors or the background) could be extracted and recreated from the video sequence without having to decode the other region (the background or the actors, e.g., with this latter data remaining in a compressed format). If it is desired to edit a region, for example, to change the color of a particular actor's shirt, this "color correction" may be accomplished without necessarily decoding the background region, and a color corrected signal may then be re-encoded into bit stream format and inserted in the place of the original bit stream data for the set of actors. [In this example, the background data would not have to be changed, although it might be necessary to modify some front end parameters for the image frame, such as buffer sizes.]

A "data group" or "region group" refers to any set of data that is to be grouped together across several frames; the individual pixel values of a data group may change from frame-to-frame. For example, if it desired to independently encode a mountain that appears as one background image of a moving scene, and each frame features a slightly different perspective of the mountain, the mountain might be one data group; its relative size and color might change from frame to frame, but in each frame its data would be grouped together as a "region" and each region would be separately encoded in each frame, such that across a frame sequence, the entire mountain can be singled out and extracted and decoded, independent of other compressed data.

These and other defined terms will be further described and applied below.

II. The Principal Parts.

FIGS. **1–9** are used to help describe the operation of an encoder and transcoder. The encoder is used both to newly encode video signals, and also as a part of a transcoder which either converts a compressed signal to an ICR format, or reassembles an edited sequence into a compressed format.

Ideally, the result of either of these (encoder or transcoder) processes is an ICR signal that may be displayed or further used in editing. Several preferred formats for this signal are described below, with reference to FIGS. **10–24**. One format involves embedding region information directly within an output signal. For example, in filming a program, it might be desired to film actors or other objects against a blue background, such that the actors or objects may later be combined with a specific scene (e.g., a jungle scene) via electronic "blue matting." In this instance, it might be desired to separately encode the foreground (the actors or objects) as one or more ICRs and the background as another ICR to minimize processing required in the "blue matting" procedure. Since the foreground actors or objects in this example may move in position with respect to each frame, it may be necessary to specify directly in the header information for a compressed scene exactly where to find each ICR among the bit stream data for that frame; several formats for providing "region maps" are described below, such that each object can be extracted from bit stream data for each frame. Stated somewhat differently, this first "region map" format involves identifying each ICR in bit stream header information, such that the output signal can be examined, ICR position derived from the signal, and this information used to extract each ICR from each frame. A second format does not use this embedded "region map" information, but instead relies upon default or constant region information. For example, it may be desired simply to have a static data group (e.g., a static object or fixed region such as the bottom right hand corner of each frame) that is constant for all frames of a "GOP" or image sequence. In this instance, information on region location could be provided in a user manual, indicated on a label for a video disk or tape, or via some other mechanism, and a specific map for each frame would not be needed.

Finally, the remaining FIGS. are used to exemplify some uses for a signal having ICRs and a decoder, respectively. For example, one use of an ICR signal is for enabling efficient and quick editing by extracting and changing a specific data group only. Techniques and systems for making use of ICRs and the specified signal formats are described furthest below, with reference to FIGS. **25–29**. These FIGS. also illustrate operation of a decoder that may be used to generate spatial domain data that can be employed for such efficient and quick editing.

With this explanation in mind, the making and use of a preferred encoder and transcoder will now be further described.

III. Operation of Preferred Encoder and Transcoder.

A. Overview.

FIG. **1** illustrates the operation of a basic encoder or transcoder that implements principles of the present invention. Preferably, one image processing system accomplishes both functions and accepts any of (a) "raw" or uncompressed video **103**, (b) already compressed video **105** without ICRs which is to be processed to convert it to an ICR format, or (c) already compressed video **107** having ICRs which are to be edited or processed in some manner. As indicated by blocks **109** and **111**, compressed video must either be entirely bit stream decoded if there are no existing ICRs or, if there are existing ICRs, then those ICRs that are to be selectively edited must be decoded. It should be noted that one purpose of the encoder or transcoder is to provide a compressed output signal, and many of the procedures described below are utilized to take shortcuts (e.g., improve processing speed) in deriving such a compressed output signal.

The encoding or transcoding process typically involves presentation of some display to a user who oversees the encoding process. A "user" as applied in this section of the disclosure refers to one operating the encoder or transcoder to cause the selection of, or redefinition of, regions that will be independently coded. Typically, at least one static frame will be displayed which permits the user to select groups of data that will be independently coded; the user can "drop and drag" a cursor over image area to select an arbitrary region on the screen. This region may be made static for all frames selected, or it can be used initially identify an object, with image processing software operating to automatically track the object's movement through multiple frames and to select suitable corresponding regions throughout those frames using well known tracking and image detection routines. A primary purpose of these routines will be to provide a preliminary selection of object boundaries based upon a frame range specified by a user. If existing video already has ICRs, then the display functions will cause each existing ICR to be highlighted, and permit a user to change existing boundaries or add or delete ICRs.

Importantly, each frame to be visually displayed to the user must typically be decoded, but as is implied by FIG. **1**,

not all frames in a sequence or program need to be displayed or decoded. For example, if a user selects a lower right hand corner of each image frame (e.g., a 4×2 macroblock area for all frames), then the encoding software can automatically encode the entire frame range of interest without requirement of decoding that entire frame range for user display.

Function block **113** represents the various functions associated with region selection, including display, and these functions will be further explained below.

Once regions have been selected by the user and defined over the desired frame range of interest, the image processing system then encodes (or transcodes) the selected range of video, as indicated by master function block **115**. During this process, if prior compression data is available for data which has been unaltered, that data is preferably re-used to save time that might otherwise be required in computing new compression data for unaltered regions, as indicated by block **117**. Details are described below for one system that permits image processing software to track exactly which image frames have altered and in which manner alteration has been occurred. As part of the preferred encoding process and format, a region map can be developed for each frame of a group of pictures ("GOP") which indicates how each ICR is to be "sliced." The GOP is then compressed according to these region maps, and the result of this process ideally is a bit stream with independently coded regions. These operations are indicated, respectively, by blocks **119**, **121** and **123**. The bit stream is then suitable for storage or transmission, and is inherently suited for optional editing a portion of the bit stream without having to completely decode each entire frame of interest, as indicated by an optional process block **125**.

A significant time advantage is provided in compressing a signal where prior compression data is available, as indicated by function block **117** in FIG. **1**. To this effect, for data which either has been edited, or which has not itself been edited but is dependent upon an anchor region (where either the dependency upon the anchor frame or substantive content of the anchor region has been edited), such data is newly encoded from spatial domain data and then mixed with re-used, prior compression data as indicated by blocks **127**, **129** and **131**. Whether prior compression data can be re-used is a question of tracking, since one dependent image frame can depend upon another, which can depend upon another, and so-on. Since ICRs in the preferred embodiments must depend solely upon one another, i.e., motion vectors in one frame can point only to the same object in an anchor frame, then any change outside the ICR will not affect any dependent frame. However, any editing that provides frame re-ordering or that alters data content of an anchor frame will also probably affect all dependent frames which stem from that anchor frame. Consequently, tracking software preferably keeps track not only of changes made to the substantive content of a current frame, but also to any changes made to corresponding regions of an anchor frame. The tracking software preferably creates tables during this tracking process that can be readily used to determine whether compressed input video (if available) may be directly re-used as part of an output signal. Stated again, preferred tracking software that encompasses those functions will be further described below; information of this tracking software may also be gleaned from U.S. patent application Ser. No. 09/235,101 now abandoned for "Image Compression Featuring Selective Re-Use of Prior Compression Data," filed on behalf of inventors Susie J. Wee and Marc P. Schuyler) on Jan. 21, 1999, which is hereby incorporated by reference.

FIG. **2** illustrates various physical components used to implement an encoder or transcoder **101**.

Typically, the system is based upon an image processing computer **133** having an associated monitor **135** and software **137** which controls the computer's operations. The computer **133** may be a conventional computer workstation and it may also be a specialized digital editing machine used by networks, post-production houses and others. Typically, a conventional workstation will be retrofitted to have MPEG decoders and other equipment (not shown in FIG. **2**) that facilitate video processing, including various frame buffers and a digital signal processing chip that operates collaterally to a workstation's CPU. The frame buffers may also be implemented in conventional computer memory, although typically in the case of a conventional workstation, it is desired not to burden the CPU with decoding and frame memory management functions.

The computer **133** receives a video input from a conventional video source, such as a tape source (video, telecine, or other image source) **139**, a disk player such as a DVD player **141**, or a satellite, cable or other feed **143**. Sometimes, it may be desired to mix another image with this video input, such as a foreground image (e.g., a TV station logo) or a background image, and such an optional second feed is represented by the reference numeral **145**. [There may be third and fourth feeds as well; for example, it may be desired to splice multiple commercials into a live feed of a sporting event, and each commercial might be supplied via an independent and additional feed. These optional feeds are not illustrated in FIG. **2** and it should be understood that reference numeral **145** represents any additional feed that is to be combined or mixed with the input video **139**, **141** or **143**.] As a result of the processing performed by the preferred encoding/transcoding device, an output signal is generated and compressed to a bit stream format and is either stored (e.g., on tape, in computer memory or on disk) or transmitted live (such as by satellite or over the Internet), as represented by reference numerals **147** and **149**. Finally, the computer **133** receives user commands from conventional user interface equipment **151**, which can include a mouse, keyboard, digitizing pad or other equipment.

FIG. **3** also provides flow of the preferred encoding process. In FIG. **3**, the variable I refers to "image," while the operand [n] indicates that the preferred system is operating upon digital samples of different frames; n denotes data for the current frame, n−1 denotes data for an immediately prior frame, and n−2 denotes data from two frames prior. In this case, frame n−1 is presumed to be an anchor frame for frame n, and frame n−2 is presumed to be the anchor frame's anchor frame. The variable I' indicates reconstructed (i.e., decoded) image data including quantization errors.

As indicated by FIG. **3**, the encoding system receives digitized video **161** that is to be encoded, together with region selection information **163**. The digitized video is stored in a buffer on a frame by frame basis. (preferably using a circular frame buffer that holds a number of frames at a time) and is used by motion compensation and independent region motion estimation systems **165** and **167** to calculate a block of data estimates (i.e., the "closest match"), indicated reference numeral **169** in FIG. **3**. This closest match data is provided from decompressed image data supplied by inputs **181** and **183** (these inputs incorporate quantization errors from an anchor frame's compression, just as would be seen by a decoder). The closest match information is passed to a first summing junction **171** which calculates residuals, e.g., a block of different values obtained by subtracting a "closest match" of an anchor frame from the

data block under consideration. From there, a discrete cosine transform is applied to the residuals, which are then quantized (as collectively indicated by function block **173**) to yield a data block with non-zero entries herded in an upper left-hand corner of the data block. This information is then passed to an independent region ("IR") coder **175**, which encodes motion vectors from the motion estimation system **165** together with the quantized data. The motion vectors have already been limited by the motion compensation system to point only to associated data in anchor frames, as appropriate, and the IR coder **175** is supplied with region selection information **163** for proper insertion of slice codes, such that each region is comprised of discrete slices. The IR coder applies run-length encoding and Huffman coding to quantized data, and inserts appropriate MPEG header codes (including slice codes, as further discussed below) to generate an output bit stream **177**.

Importantly, not all image frames are compressed using motion vectors; using a M.P.E.G.-2 process, all data within "I" frames are encoded without using motion estimation and compensation, and select data blocks within "P" and "B" frames may also be encoded in this manner. That is to say, a "P" frame could have null motion vectors and be locally or entirely coded as an "I" frame notwithstanding its "P" frame designation, and a "B" frame could be encoded to have data dependencies only in one (forward or backward) direction, or without any dependency. A control routine **179** determines this encoding according to well known procedures and algorithms developed for M.P.E.G. coding. The control routine **179** also limits the motion estimation in its search procedures. That is to say, whereas conventional motion search would focus upon a "closest match" location within an anchor frame and define a search window about that location, the control routine **179** only permits "closest match" locations which correspond to the same object or region in an anchor frame, and it limits the search window to also lie within this object or region. In this regard, region selection information is preferably pre-computed for the entire sequence of interest, such that the encoding system "knows" where the corresponding regions are within the anchor frame(s), if any; ICRs preferably are described by a unique naming attribute, such that corresponding regions from different frames may be readily associated (e.g., they have the same name). If no corresponding region is available in an anchor frame, or if the closest corresponding region location in an anchor frame is significantly different in position relative to the data block under consideration, then the control routine **179** may decide to encode the data of interest in an independent manner (i.e., encode "P" frames solely in an independent manner or "B" frames in a unidirectional manner).

As previously mentioned, inputs **181** and **183** are provided to the motion estimation and compensation systems for use in compressing subsequent dependent frames; these inputs are derived just-coded compressed video to provide decompressed video in the same manner as would be seen by a decoder. This procedure (i.e., the seemingly unnecessary use of encoded-then-decoded video) is necessary, because the quantization procedure usually rounds some values and might introduce errors that would "snowball" unless quantized image data were used in the motion compensation process. The decoding of data is indicated in FIG. **3** via a function block **185**. Resultant residuals for an anchor image estimate, n−1, are then used for the encoding or a current frame n. A second summing junction **187** is used to construct an anchor image estimate I' [n−1] from both the anchor image residuals **189** and image data **191** from any anchor frame's anchor frame I' [n−2].

With the operation of the preferred encoder and transcoder thus presented, region selection and tracking will now be described in additional detail.

B. Region Selection in the Preferred Embodiments.

Region selection is preferably accomplished using computer workstation software and standard user interface tools, including a mouse and computer display monitor. Ideally, this software handles different types of video inputs, including inputs which may or may not be compressed, and compressed inputs which may or may not already have ICRs. Preferably, the hardware being used has a MPEG decoder, frame grabber or similar add-on computer hardware that provides for localized storage and display of a small number of frames on a real-time basis. The preferred region selection process **113** is further represented by FIG. **4**, which shows additional steps performed within the block **113** from FIG. **1**. FIG. **4** presents detail as to the initial processing, storage and display of images; function block **215** represents the actual region selection process, and will be further described in connection with FIG. **6**.

Initially, it should be noted that preferred software provides the user with the ability to play video forward and backward, to stop and pause video, and to fast forward and fast reverse displayed video. In addition, the preferred software provides the user with the ability to select a specific frame (based on frame number or time) and to automatically scroll to the selected frame. The software, in combination with the hardware discussed above, will automatically display images as appropriate on the display monitor, and provides any decoding functions to display the desired frames of the video.

Armed with these abilities, the user begins by selecting a specific frame, as indicated by block **201** of FIG. **4**. If the input video was in compressed format, the entire compressed GOP and decompressed GOP for the selected frame (i.e., including both prior and anchor frames) are both stored in quick-access memory, such as indicated by blocks **203**, **205**, **207** and **209**. At this point, the preferred software identifies any existing regions in the frames being displayed, as indicated by block **211** of FIG. **4**; this region information may be supplied via region maps embedded within the video signal, or the software may be configured to display constant geographic regions, for example, a "box" that will be used for logo insertion. Any existing regions preferably have a highlighted outline superimposed upon the displayed image, together with a display of region number or naming attribute (such a display is indicated by FIG. **5** as discussed below). [Since as also discussed below, each region is encoded as a discrete number of image slices, an outline of regions is fairly easily derived lie at macroblock borders.] The image display software ideally will afford a zoom function **213**, such that the user can see region boundaries in additional levels of resolution. At this point, the user has decoded some amount of image data as appropriate (preferably an entire GOP), and is presented with a display of an image frame with existing regions highlighted for possible editing of those regions. The creation of new regions or editing of displayed existing regions is represented by block **215** and, again, a zoom function **213** is provided during this process to enable a user to fine tune region boundaries.

FIG. **5** is a hypothetical depiction of a display which highlights regions in relation to an image screen **217**. In particular, two regions are indicated including a first region **219** that takes up most of the screen and displays the designation "R2," and a second region **221** (bearing the designation "R1") that takes up the bottom right corner of the screen. Such a second region might be used, for example,

for logo insertion. Ideally, the software permits adjustment of these regions by "dragging" boundaries, such as the upper boundary found within a cursor tolerance range "D;" the region boundary will typically fall at a macroblock boundary.

FIG. **6** provides additional detail as to how a user selects new regions or changes existing regions, and elaborates upon the functions performed by block **215** of FIG. **4**.

With an image displayed on a screen, a user picks:a point within the screen, and the software determines whether the point is "close enough" to a region boundary (such as within the tolerance "D" mentioned above). If the answer to this inquiry is affirmative, the software presumes that the user wishes to edit the boundaries of the existing region. These functions are variously performed in blocks **223**, **225** and **227** of FIG. **6**.

As indicated by function block **229**, if the user-selected point is not "close enough" to a region boundary, the software proceeds to "guess" a new region based upon image attributes in the vicinity of the selected point. This "guess" is preferably based upon standard image processing techniques, such as hue or intensity similarity, edge detection or other common image processing techniques or any mix of them. Preferably, a mix of techniques is applied, with technique emphasis based upon a weighting function **231** and user-supplied parameters; in this way, each user can tune automated region detection functions to his or her interests. A "guess" may also be based upon pre-defined geometric selection parameters (represented in box **233**), such as a rectangular region used for logo insertion. If a user selects regions such that they overlap, the software preferably subdivides the regions to avoid overlap (e.g., two overlapping regions would become three or more regions); this subdivision is not required, and whether regions may overlap is discussed below in connection with object boundary treatment with the preferred signal format.

Once a region has been automatically "guessed" based upon the user-selected point or area and automatic extrapolation of a region, the software preferably permits a user to adjust region boundaries by "dragging" those boundaries in either rectangular and non-rectangular fashion. [Here again, the user selects the existing region by placing a cursor "close enough" to the particular region boundary and clicking his or her mouse.] A zoom function (not indicated by FIG. **6**) may also be employed if desired to ensure that the user-selected region encompasses exactly the image data desired by the user. Further, if desired, the software may include a feedback function that automatically adjusts the user-supplied configuration parameters (or a temporary copy thereof used for one frame range) to more accurately reflect the user's choice of region. With the region accurately defined, the user selects a menu function or icon (not indicated in FIG. **6**) to define a frame range to which the region criteria is to be applied. For example, as indicated by block **239**, the user is preferably given choices of selecting the current frame only, a range from the current frame to the GOP end or start, or a range to or from a specific number of frames or to a specific frame number. These choices are only illustrative, and actual implementation is a matter of software design choice. With a frame range having been selected, the user then selects a menu function or icon to cause automatic application of the region selection information and parameters to all frames within the chosen frame range; the user may scroll through a display of all such frames if desired (with provision of a graphical display of highlighted region boundaries such as indicated by FIG. **5**), and may further fine-tune individual boundaries. These tasks are represented by function blocks **235**, **237**, **239**, **241**, **243** and **249** of FIG. **6**.

As referenced by numerals **245** and **247**, each time the displayed frame is changed, boundaries for the various regions in the frame currently under display or processing are written to a RAM table having all region information for that specific frame number. For example, if (as is preferred) each region is constrained to fall at a macroblock boundary, the RAM table could consist simply of an identification of which macroblocks (by macroblock number) correspond to each region. If an existing region (reflected by the input signal) has been changed, it is also desirable to set a table value dedicated to the existing region, for tracking purposes. If the altered frame is an anchor frame, then the software automatically identifies any depending frames' regions and begins (if applicable) or sets table values for those frames and sets similar values for those regions. This function is used to trigger compression analysis of affected portions of any dependent frame (even if image data within the dependent frame has not been altered), and will be further discussed below in connection with the tracking software.

Finally, with regions having been created and mapped to entire GOPs or an entire sequence, groups of associated regions are preferably named using ASCII text, preferably using a descriptive naming attribute (e.g., specific actor or object name). This naming attribute is preferably included in header information for a MPEG sequence, such as will be discussed below in connection with the preferred signal format. As an example of the utility of this feature, the embedding of region naming information directly into bit stream header information will enable downstream selection of a region for editing directly from the encoded bit stream (an actor's shirt, for example, may be separately named and later, recognized by this naming attribute and independently extracted from an encoded bistream). As will also be discussed below, regions preferably are grouped in one of two general ways, namely, as "local" region groups (e.g., region definition spans only a single GOP or less) and "global" region groups (e.g., region definition spans more than one GOP). Two global region groups preferably are not permitted to share the same name, and two local region groups in the same GOP preferably are not permitted to share the same name. The naming function is designated by reference numeral **251** in FIG. **6**. As used herein, a "region group" will refer to associated regions from different frames that are associated together, e.g., they are defined to refer to a single image area of interest or collection of items that are to be coded for independent extraction as a unit from a compressed bit stream; typically, the descriptive name attribute referred to earlier will be shared throughout a single region group.

Importantly, the tasks outlined above are easily implemented by a skilled software designer. Image detection software and processing techniques are well known in the art, and are many times found in commercially available software. It is well within the abilities of a skilled artisan to implement, modify or add to these features in order to provide similar results.

C. Compression and Formation of an Output Signal.

As indicated in connection with block **119** of FIG. **1**, once region selection has been performed, the software prepares to compress the frames of interest. It will be recalled from FIG. **4**, however, that region selection information is needed in order to limit motion search; any motion vectors from one region of a frame may only point to data in an anchor frame which is the same region group. In order to limit motion search in this manner, it is first:desired to determine how

regions will be sliced when it comes time for bit stream compression; this function is illustrated by block **119** of FIGS. **1** and **3**, and is explained in greater detail with reference to FIG. **7**.

In particular, the software first proceeds to determine for a frame the precise number of regions in the frame; this information is provided by the RAM table discussed above in connection with FIG. **6**. The software also determines whether the original video input had ICRs; if so, and if the number of ICRs has been changed, then the software notes this information for the purposes of updating its information as to the number of local region groups and global region groups in connection with the preferred signal format. [As indicated below, in this preferred format, sequence or GOP header information sets forth the total number of region groups for the sequence or single GOP, as appropriate; this information is used to determine region map (table) size for each frame.] The various functions just identified are indicated in FIG. **7** by reference numerals **253**, **255** and **257**.

The software then determines slice boundaries, using the RAM table information mentioned above in connection with FIG. **6**. In particular, the software determines where each image slice should begin and end, and which region each slice should be associated with. The software then calculates a mapping, indexed by region, that identifies each image slice for the frame that must be decoded in order to convert the entire region to the spatial domain; it stores the slice boundaries in RAM for each frame in the sequence and it also stores an indicator of the total number of slices for the frame (which is used for frame header information). These functions, respectively, are indicated by reference numerals **259**, **261**, **263**, **265** and **265**. With region information thus available, video may be compressed as necessary in order to generate an output signal.

Compression is performed in a typical fashion, except that unaltered prior compression data from the input signal (if any exists) is re-used if possible; also, motion vector search and compensation is limited such that any resulting motion vectors point do not point outside the pertinent region group. This latter function can be performed in several manners. First, motion search can occur in a normal manner (where a given size search window is scanned to yield an absolute sum of residuals for each "closest match" candidate), except that with each new candidate and before any pixel-based comparison, the search algorithm uses a decision block to determine whether the candidate falls within the region group. If the candidate is outside of the region group, the software discards the candidate and proceeds to the next candidate; if the software finds no possible candidates using this procedure, it simply encodes the block in question without any data dependencies. This operation is preferred, as it is likely the simplest to implement. In the case of fixed-step methodologies, the search algorithm can inhibit step directions that cause the search to more further away from the proper region group as well as any "closest match" selection from outside the region group. The compression software could also build a search window or step strategy around the location of the region group.

The tracking of edits and the re-use of prior motion vector data will now be further described; this task is identified by function block **117** appearing in FIG. **1**. In particular, the compression software relies upon tracking of edits and changes (both to the current frame and to the anchor frame) to determine whether prior bit stream data or motion vector data may be re-used in building an output. To this effect, and as generally described by the co-pending patent application referenced above, a "registry of edits" is employed for each edited frame; each time a frame having pre-existing ICRs is decoded, a table is created for that frame with a two-bit value associated with each region of that frame. The table is created only for those frames that have been decompressed for editing or ICR creation, and entries can represent several different types of edits. The absence of a table for a frame that is to be compressed indicates that any prior bit stream data may exactly be passed to the output for a frame. If a table does exist, the software polls the values for its regions to determine appropriate processing.

First, if a region in both (a) a current frame the pertinent anchor frame (or frames) has not been substantively altered (e.g., regions have not been added or redefined), and (b) temporal dependence upon any corresponding region of an anchor frame has also not been severed, then the software may re-use all data for the current region. Otherwise stated, the bit stream data in this case would also be exactly passed to the output signal, although it may be necessary to redo the header information. The values of the registry of edits are initially set to a default (e.g., "00") and are changed as appropriate.

Second, if there has been some adjustment of region boundaries (e.g., re-definition of the existing region or creation of a new region inside an existing region; for either the current frame or any anchor frame), but no change to image content, then the software proceeds on a motion vector-by-motion vector basis. In this regard, a change in region boundaries may or may not invalidate motion vectors of the input signal; the software polls each motion vector to determine whether the motion vector still points within the region group, and performs new search and motion compensation for any motion vectors which cross region group boundaries. Bit stream formation in this event is performed anew for all slices in the adjusted region. This type of editing could be reflected by a binary code such as "11" in the registry of edits.

Third, if image content has been altered in a manner which invalidates any original motion vector data, (e.g., image data has been changed have been changed for the current frame or any pertinent anchor frame such as by signal mixing or logo insertion), then those regions and any associated regions in dependent frames are preferably completely re-compressed from the spatial domain. The system then creates new bit stream data from such re-compressed data for formation of an output signal. To facilitate this processing, at the time of substantive altering of frame content, the software writes another specific value into the registry of edits, specifically for those regions that have been modified; for example, a code such as the binary value "01" could be used for this purpose. The software here also preferably tracks all frames depending upon the modified frame and likewise writes a similar value into these regions.

Fourth, if underlying image content has been altered in a way that does not seriously impact any original motion vectors (e.g., color correction only is performed upon the frame or an anchor frame), it may be possible to re-use the original motion vectors while calculating new residuals. A code such as the binary value "**10**" could be used for this purpose, and is again written into all depending regions in the same region group.

A "registry of edits" **269** for a single frame is illustrated by FIG. **8**, which indicates five hypothetical regions; a first region represents a billboard appearing in the image background (e.g., a billboard for the popular soft drink "COCA-COLA"), a second region represents the bottom right hand screen corner for use in logo insertion, a third region represents an actor's orange shirt (appearing in foreground),

and fourth and fifth regions represent remaining foreground and background, respectively. [In this example, it will be assumed that objects always end at a macroblock border; as will be mentioned further below in connection with signal formats, such is generally not the case, and border regions between image objects may themselves be encoded as independent regions.] For purposes of this example, it should be assumed that one desires (a) to modify the "COCA-COLA" wording to instead reflect the corresponding trademark in Chinese, (b) to insert a logo in the bottom right hand corner of the screen, and (c) to color correct the actor's orange shirt to instead be white. In this instance, using the binary codes indicated above, the registry's values might be as indicated in FIG. **8**.

Notably, the registry of edits preferably includes some manner of indicating temporal re-ordering of frames (such as might be required for editing of the input video to impart fast-forward, reverse play, and similar effects to the output video signal). This indicator can be a single bit or flag, created for each registry of edits, which is set only if the current frame is a dependent frame whose dependency has been "cut." If there has been such a temporal re-ordering, then the current frame preferably completely re-compressed and re-encoded from the spatial domain. If frame order is simply reversed (i.e., dependency has not been severed), then for "B" frames, motion vectors are simply interchanged (i.e., forward motion vectors become backward motion vectors and vice-versa); if a frame re-reordering affects a "P" frame, the "P" frame is preferably converted to the spatial domain and then is re-compressed, for example, as an "I" frame.

FIG. **9** provides additional detail as to the flow compression algorithm indicated by block **121** of FIG. **1** and of some of the processes just described. For ease of description, FIG. **9** reflects implementation of a device which simply imparts ICRs to input video, and does not provide any editing abilities (other than adjustment of existing regions); an editing device would preferably employ the more plenary set of functions just described.

As seen in FIG. **9**, slice boundaries are first retrieved for the current frame from RAM, as indicated by block **271**. If the original input video was compressed, then prior compression data is potentially available for re-use; if there is no prior compression data available, then the software proceeds to decide upon a frame type ("I," "P" or "B") and to use the region map and slice boundaries to compress the frame; if the frame type is dependent, then search is limited to point to only corresponding image areas of an anchor frame, as has already been described. These functions are reflected by reference numerals **273**, **275** and **277** in FIG. **9**.

If prior compression data is available, the software retrieves frame type ("I," "P" or "B") and tentatively applies the same frame type to the corresponding output frame. If no RAM table exists for the frame (the RAM table should indicate frame number, which is used for comparison), the software presumes that there are no changes to the video input and passes original bit stream data directly to the output signal. If a RAM table does exist, the software proceeds on a region-by-region basis, using the table to determine the type of processing. For each region, if there has been (a) no substantive editing (e.g., boundary movement, new region created within, color correction, etc.) in that region and (b) no substantive editing of any anchor frame region for the pertinent region group, then the original bit stream data for the region and its slices are directly used as part of the output video stream. [Since editing of other regions in a frame may affect slice numbering and other header information, frame and slice header information may require adjustment; this adjustment is discussed further below, in connection with the bit stream encoding functions indicated by reference block **123**.]

In the context of an encoder/transcoder that simply creates regions (and does not perform editing), any substantive alteration of frame content will simply consist of manipulation of region boundaries; consequently, FIG. **9** indicates that for regions having substantive frame alteration, the software inquires on a motion vector-by-motion vector basis whether region group boundaries are crossed. If the answer to this inquiry is "yes," then motion compensation for the offending data block needs to be re-performed; if not, the motion vectors and associated residuals are passed to the output. These functions are all indicated by blocks **279**, **280**, **281**, **283**, **285** and **277**. In implementations where the encoder/transcoder will be used to process edited video, it may be necessary to perform further inquiries, such as decision blocks which check for registry values as discussed above to determine whether image content has been altered.

Bit stream encoding is processed in the manner set forth by FIG. **10**, which elaborates upon the functions performed by process **123** of FIG. **1**. In particular, re-used bit stream data is exactly passed to the output signal if it represents an unaltered frame; this operation is represented by block **287** of FIG. **10**. Alternatively, for frame data which is a mixture of original bit stream data (for unaltered regions) and motion vector and residual data (for regions which have been substantively altered as to region definition or image content), the software bit stream encodes the motion vector and residuals data, calculates new slice and frame header data for the frame (including new slice numbering), and ideally passes this data to the output signal; since Huffman coding will be common to the entire frame, it may be necessary to re-code the bit stream data, and the software makes this determination based upon a polling of the new residual data. The software preferably applies some quantization (at the expense of image quality) in order to re-use the original bit stream data, but is also imparted with ability to initiate re-coding of the bit stream data. For frame data which has been completely compressed anew (because input video was originally uncompressed or because of image mixing or logo insertion), such data is completely encoded anew, according to well-known procedures. These functions and the summing together of bit stream frame data are variously indicated by reference numerals **287**–**311** in FIG. **10**, and the final product is an output video signal **313** having ICRs as desired.

With the operation of an encoder and transcoder thus described, several different signal formats will now be discussed.

IV. Use of a Special Signal Format Having Region Maps and Coding Information Pertinent to ICRS.

As discussed above, the present invention can be applied to take video which is "raw," uncompressed data and encode it in an ICR format, and also to take encoded, compressed video and transcode it to an ICR format. This latter operation might be especially useful for already-compressed video which is to be syndicated or distributed for use by a number of different entities; alternatively, it might be desired to transcode video to an independently coded region format if there is a foreseeable need to extract objects from the video. For example, if video is taken of actors against a blue screen background (for "blue-matting" purposes), it normally would be desired to independently code the actors such that they may be readily extracted and mixed with replacement background images.

Video which is compressed with later editing or object extraction in mind is preferably placed into a special signal format that defines each region group and that textually describes each group. The preferred format for this video is explained with reference to FIGS. **11–24**. In particular, this format includes special control codes and information which may be inserted into user defined portions of sequence, group of picture (GOP) and frame level header information of a MPEG video sequence. Use of this information enables a decoder or editor to recognize from the compressed image signal itself which slices of an image frame must be decoded in order to edit or extract a select object or location in the screen; more particularly, use of this format enables a decoder or editor to track a region group through multiple frames, even if the relative positions of individual regions in the group change from frame to frame.

FIG. **11** is used to explain a MPEG sequence and its hierarchy of header information. FIGS. **12–14** illustrate a part of a video sequence including three frames of a flying ball; the ball is seen to move from right to left through these frames. The preferred signal format includes region map information for each frame, indicated using FIGS. **15–20**; one region group could be defined as corresponding to the ball, while another region group could be assigned to background not having any ball, and a third region group could be assigned to image portions having both ball and background. Finally, FIG. **24** is used to illustrate the use of a region group dedicated to the lower right hand corner of a television image, for logo insertion.

FIG. **11** shows a MPEG sequence **315**, including several tiers of information. In particular, FIG. **11** illustrates a sequence level tier **317**, a GOP level tier **319**, a frame level tier **321** and a slice level tier **323**. In accordance with the preferred embodiment, header information for the first three of these tiers is formatted to include control commands and information that facilitate extraction of ICRs from the video sequence; that is to say, a specific data format is preferably used to facilitate use of ICRs. In the example presented in FIGS. **12–14**, it will be assumed that the video sequence is compressed and coded and that it is desired to extract the ball presented by these FIGS. and to change the color of the ball from white to red. Since it is unnecessary to decompress all image data for all frames containing the corrected ball and time consuming to recompress an output signal if a compressed output is desired, an editor or decoder preferably decodes only the region groups containing the ball, and it corrects these region groups only for color. Once editing is complete, the editor or decoder compresses the color corrected region groups and re-inserts these corrected region groups back in place of the original information representing the ball. The editor or decoder can also extract objects in select regions, e.g., the ball illustrated in FIGS. **12–14**, for use with other images. Since the ball is seen in FIGS. **12–14** to occupy only a small portion of each image, it should be apparent that the preferred embodiment and preferred data format operate to substantially reduce the processing time that might otherwise be required to produce a compressed, edited output signal.

A "sequence" **315** can be an entire movie or portion thereof and, in the example of FIGS. **12–14**, it will be assumed that the sequence includes a great many frames not illustrated. Each sequence includes header information that contains digital parameters used to decode and display images appearing in the sequence; in addition each sequence header contains space for user defined control commands and information. In connection with the preferred signal format, this information (at the sequence level) includes definition of a number of global region groups defined throughout the sequence. For example, if the video sequence represented by FIGS. **12–14** is part of a hypothetical movie about a child soccer player, one global region group could be defined to be a child, while another region could be defined to be a ball. In practice, the global region groups are preferably defined textually (e.g., region **1**=ball, region **2**=child) within the user defined portions of the sequence header, e.g., using control codes and ASCII text. In this manner, one desiring to edit an image sequence need only examine the electronic header information within the sequence to learn from the signal itself exactly how regions have been independently coded and what these regions represent.

As seen in FIG. **11**, the beginning of a sequence in a MPEG format is typically recognized by examining the encoded bit stream and detecting twenty-three consecutive zeros, followed by a "one" and the eight bit sequence "10110101" (in base sixteen numbering, this "sequence start code" value is "000001B5" and is designated by the reference numeral **325**). Sequence header information **326** then includes various parameters such as picture size, bit rate, buffer size, video standard, and similar parameters, recognized by control codes that proceed these parameters. A user data start code **327** (twenty-three lead zeros followed by "1B2") is then utilized and followed with special codes defining any global region groups **328**. For example, a specific bit pattern (e.g., a code such as twenty-two lead zeros followed by "1100") may be chosen to denote the naming of a global region group, followed by a text comment and another code for naming a second global region group, and so on. FIG. **11** indicates the creation of "j" global region groups **328**. Once all user information is complete, a GOP start code **329** can be presented.

In a typical image sequence, a user start code might be followed by many different types of information, such as close captioned information. In the context of an editor operating in conjunction with the present invention, it may be desired to skip this information and proceed directly to region group definition and region map information, and therefore it is preferred to use a coding scheme that renders these types of information readily apparent in examination of an encoded bit stream. One skilled in the art should readily be able to select a coding scheme that permits extraction of region information from among other user data; for example, since MPEG start codes usually commence by twenty-three lead zeros followed by a one, a readily detectable "region information" coding scheme might be twenty-two lead zeros followed by a one, and a binary pattern representing (a) a global region group definition ("100"), (b) a local region group definition ("101"), (c) a total number of slices for the current frame definition ("001"), (d) a group map preamble code ("010"), and (e) a region map preamble code ("011"). These codes could be inserted at the end of any user data already within the image sequence, such that the end of a particular type of region information would be signified by either twenty-two or twenty-three lead zeros (indicating more region information, or another MPEG start code, respectively).

A sequence includes multiple GOPs **331**, which typically each have on the order of one dozen to a couple dozen image frames **332**. Each GOP is self-contained in the sense that while it typically includes I, P and B frames, no dependent (P or B) frame points outside of the GOP; that is to say, all anchor frames for the GOP are found only within the GOP. Each GOP also contains header information **333**, which is recognized by detecting a GOP start code **329** of twenty-

three leading zeros followed by the nine bit sequence "110111000" (in base sixteen numbering, this GOP start code is "000001B8"). The GOP header information in connection with the preferred signal format also preferably includes a user data start code **334** ("000001B2") followed by a group map identification code and group map indicating which global region groups are present in the GOP; FIG. **11** indicates that this group map for each GOP includes "j" values, labeled v_1 through v_j in FIG. **11**.

For example, in FIGS. **12–14**, one exemplary GOP is presented consisting of three image frames **335**, **337** and **339**. If there are only two global region groups in the sequence, and the child is not present in the GOP of

FIGS. **12–14**, then a group map for this GOP might contain a bit pattern such as the value "10" (seen in FIG. **16**), indicating that the first region (the ball) is present in these images, whereas the second region (the child) is not present and consequently will not be represented by individual frames' region maps; an exemplary group map **341** is indicated in FIG. **16**. The user information for the GOP also includes region group information **343** for locally defined region groups; for example, the GOP of FIGS. **12–14** might include ASCII text information identifying that a third region is a blue sky background to a flying ball, and that a fourth region is a transition between baseball and sky. A locally defined region group, as mentioned earlier, could be signified by twenty-two lead zeros followed by "1101," followed by ASCII text naming the region group. Once the GOP level header information is complete, the bit stream includes a frame start code. The total number of region groups (global and local) is represented by the quantity "N" in FIG. **11**.

Returning to FIG. **11**, each GOP **331** includes information for multiple image frames, and each image frame includes its own header information **345**, defining important parameters such as frame type (e.g., I, P or B). Each frame is commenced by a frame start code **347** (twenty-three lead zeros followed by a one followed by eight trailing zeros, or "00000100" in base sixteen numbering), frame header information and a number of "image slices" **349**, which contain the image content for the frame. At this point, the frame start code **347** ("000001B2" in hex) is used, followed by an appropriate code and a definition **353** of a number of total image slices for the frame and by a leading code and region map **355** for the particular frame. The region map identifies which image slices are associated with each region group for the GOP; otherwise stated, the region map indicates "where" a given region may be found in the particular frame. Each slice is also signified via a start code **356**, consisting of twenty-three lead zeros followed by 00-AF (hex), indicated a slice number between 0 and 175.

In this regard, it was previously mentioned that the second global region (e.g., a child) is not illustrated in the example of FIGS. **12–14** and, consequently, there are only three regions groups in this GOP, namely, for a ball, a background, and a combination of ball/background respectively. The region maps for each of these frames therefore preferably consist of three tables, one table for each region group in the GOP, each table having one entry corresponding to each image slice in the particular frame. [Because the group map of FIG. **16** indicates that of two global region groups one is present in the GOP while another is not, the first table in the region map will be taken to correspond to the first global region group, and each subsequent table will be taken as corresponding to each locally defined region group, in the order in which they were defined. In this regard, an editor or video processor examining the sequence would be required to keep track of all globally defined region groups as well as any locally defined region groups for the current GOP. This operation is represented by the quantity "N'" in FIG. **11**, denoting the fact that at least one globally defined region may not be represented in the region map.] As alternative variations to the naming and coding scheme just described, one skilled in the art could implement a different naming or coding scheme and method of tracking region groups in an editor (e.g., instead of having the editor keep track of region group definitions and their order); for example, region groups could alternatively be redefined for each and every GOP.

In the example presented by FIG. **14**, it will be assumed that there are nineteen total image slices, such that each table for that frame has 19 one-bit entries. FIG. **15** illustrates hypothetical location of image slices for each of three data types, grouped by position and labeled by the numerals "A," "B" or "C." Data type "A" refers to image data for the ball, data type "B" refers to image data for background scenery, and data type "C" refers to boundary data for image transition from ball to background. Each data type (or box labeled "A," "B" or "C") is encoded using either of two different region mapping schemes discussed below. [Importantly, the MPEG-2 format constrains each subsequent row of image macro-blocks to be encoded as a new slice, such that there will be more slices than nineteen represented in images corresponding to this format; FIGS. **12–23** show only a few slices and regions, and are used for illustration purposes only. Conventionally, each frame in a M.P.E.G. sequence has up to one hundred and seventy-five image slices, which are separately encoded in the bit stream and are signified by slice start code consisting of twenty-three leading zeros, followed by a one, and followed by a two byte value from "1" to "AF" (175). In conventional MPEG formats, there also is a separate layer of commands associated with each macro-block of image data, but the macro-block level of information is not specially used in the preferred embodiment.]

As mentioned, two region mapping schemes are explained each as applied to FIG. **15**. In a first region mapping scheme (represented by FIGS. **17–19**), each data type "A," "B" and "C" are individually encoded as a separate region group. Using this mapping, for example, if one desired to extract a ball only from a compressed representation of FIG. **15**, one would need to identify and decode both regions "A" and "C," which would include ball data. In a second region mapping scheme (represented by FIG. **20**), only two region groups are used. A first region group is identified to include data from any image slices having a ball (e.g., any slice having data types "A" or "C"), whereas a second region group is identified to include data from any image slices having background (e.g., any slice having data types "B" or "C").

FIG. **16** illustrates a hypothetical group map **341** in this "flying ball" example, while FIGS. **17–19** illustrate the individual tables **357**, **359** and **361** for the first region mapping scheme mentioned above. In particular, FIG. **17** identifies that, of nineteen image slices indicated in FIG. **15**, only the eleventh slice has data belonging to this region (e.g., parts of the image having only a ball without any background). FIG. **18** indicates that of the nineteen slices, all but the seventh, tenth, eleventh, twelfth and fifteenth images slices have only blue sky background; finally, FIG. **19** indicates that the seventh, tenth, twelfth and fifteenth slices have both ball and background. One desiring to perform color correction (for example) upon the ball in this frame would need to decode all of the regions identified by the

tables of FIG. **17** and **19** in order to find all image data corresponding to the ball, but would not need to decode any parts of the image frame representing purely background.

The signal format includes not only the header information discussed above, but also contains compressed image data for ICRs themselves. Each region group, for example, the three region groups scheme for each of "A," "B" and "C" in FIG. **15**, require limitation during motion search, such that motion vectors and residuals for data within these regions point only to corresponding regions in a prior frame. For example, FIG. **15** represents the third frame in the hypothetical three-frame GOP of FIGS. **12–14**, whereas FIG. **21** represents the first frame, seen in FIG. **12**, where the ball is at the upper right side of the image frame. If it is assumed that the frame of FIG. **15** represents a dependent "P" frame, whereas FIG. **21** represents an independent "I" frame (as it must be if FIGS. **12–14** represent a GOP), then the motion search limitation would constrain all motion vectors in a region for "A" data in FIG. **15** to point only to corresponding region having "A" data in FIG. **21**. Similarly, all motion vectors in any region having "B" data in FIG. **15** would be constrained to point to within any corresponding region having "B" data in FIG. **21**, and all motion vectors in any region having "C" data in FIG. **15** would be constrained to point only to within any corresponding region having "C" data of FIG. **21**. This mutual independence, i.e., the limitation that data from outside a region group cannot have motion vectors and residuals pointing into the region group, is relatively important, since without this limitation, changing data in a region group of interest might invalidate motion vector and residual data from (another frame) outside the group. The motion vector and residual data contained within the image slice data (represented by the reference numeral **363** of FIG. **11**) of the preferred signal format, would be formatted in accordance with these limitations.

FIGS. **22** and **23** illustrate the two region mapping schemes discussed above as applied to the hypothetical frame of FIGS. **12** and **21**. In particular,

FIG. **22** illustrates the three-region scheme, where all region tables have now been combined into a single matrix **365** and illustrated as consecutive rows of data (each row is a region table). Since FIG. **21** presents an exemplary case of only eighteen image slices, header information for the frame of FIG. **21** will indicate a total number of slices (**18**) and software interpreting the region map information will use eighteen one bit entries for each table. FIG. **23** illustrates the second region mapping scheme;, where a matrix **367** of only two tables are used, one for data types "A" or "C" and one for data types "B" or "C". As with this region map also, only eighteen entries are used, one for each image slice. As indicated, some MPEG image signals require that a new slice begin for each row of macroblocks and, thus, a real example would typically have many more slices than eighteen or nineteen.

As can be seen from the foregoing, the beginning of a sequence, GOP, frame or slice can be recognized directly from an encoded bit stream. Similarly, all information relevant to ICRs is stored in header information, such that a distributed video includes within its digital control information sufficient data to permit recognition, decoding and extraction of image objects or locations from a signal which has been specially formatted for independently coded regions. In an application involving logo insertion, for example, the encoder (and the associated GOP and region maps) could be defined to always separately slice the bottom right hand corner of an image screen, and to define that corner as a global region group. In performing logo insertion, an editor would simply need to monitor the encoded bit stream to (a) determine the identify of the global region group corresponding to the bottom right corner, e.g., the global region group named "LOGO," (b) extract from each frame of each GOP having this global region group the table of the region map corresponding to the proper global region group, and (c) decode each image slice identified by the table. Logo insertion is then performed, with the modified image data being subjected to new motion estimation and compensation and encoded and inserted into the original bit stream, in place of the data which has now been modified. Since each region group is mutually independent of each other region group, re-insertion of modified data will not affect any other region group for the any image frame. Finally, if the modified data results in any change of bit rate or buffer information, it may be necessary modify the bit rate or buffer size for the particular frame or GOP.

FIG. **24** illustrates an image frame **369** where the bottom right hand corner **371** is reserved for insertion of an image or logo **373**, such as a local television station logo "TV**5**" depicted in FIG. **24**. In this regard, if it is desired to produce an encoded, compressed video signal for distribution and subsequent, localized logo insertion, a small rectangular region is preferably defined at a constant location for all image frames in a sequence. For example, in a sequence header, a global region group could be defined and textually explained to be a bottom-rightmost rectangle of sixty-four pixels wide and thirty-two pixels high (e.g., four macro-blocks wide by two macro-blocks high), such as a corner area designated by the reference numeral **371** in FIG. **24**. Each frame's region map would in that event contain a table expressly listing slices containing only the last four macro-blocks of the last two lines (of macro-blocks) as belonging to this region group.

Importantly, the signal formats discussed above are not the only way to independently code regions, and need not exclusively be applied to video or other image signals. For example, MPEG techniques are often applied to audio signals, and the use of independently coded regions to permit select feature extraction from a compressed signal could be applied to audio signals. Furthermore, use of a "region map" is not the only way to convey the location of independently coded regions; Information on region naming could be distributed by a mechanism other than text contained within the signal itself. As an example of this latter point, textual definition of region groups could be effected by printed text such as in a manual. In addition, a group map or region map is not necessary for many applications of independently coded regions; for example, in a logo insertion application, it could simply be "understood" that the last image slice would represent a fixed area of independent coding; an editor would not need to extract any mapping information, but could simply be programmed or operated under a user's control to extract and decode this image slice only.

With preferred examples of a signal having embedded region information thus explained, editing applications and uses for independently coded regions will now be explained in greater detail; as indicated, the processes described below should be assumed to be operable upon any compressed signal having independently coded regions, irrespective of whether the signal complies with the preferred format just described.

V. Contemplated Editing Applications.

As mentioned, the techniques described in this disclosure may be used in various parts of the film and video process; the techniques may be used in originally capturing an image

sequence, or for processing a previously captured sequence. The techniques may be used by a post-production or editing house, in connection with a film transfer (such as a telecine process) or in Internet broadcast video, satellite distribution or other parts of the program distribution process.

The techniques described in this section presume that an ICR signal has already been created and is provided as an input; a video output will also generally be an ICR signal, but will reflect some sort of editing performed upon it to take advantage of the efficiencies imparted by ICRs.

FIG. **25** shows use of an ICR signal for logo insertion (for example, by a local television station). An original compressed, ICR video signal is designated by reference numeral **375** in FIG. **25**, and is graphically depicted by a nondescript image screen **377**. It is desired to substitute a logo or other static image **379** into a predetermined geographic location of one or more frames of the ICR signal.

The system first begins by selecting the appropriate ICR that is to be combined with the logo; since the video input is assumed to already have ICRs for this purpose, the appropriate ICR is preferably automatically detected. [Automatic detection is performed either by causing system software to recognize a predetermined global region group name, e.g., "LOGO," or by having the user of editing equipment otherwise identify the region group space to be used for the insertion.] With the region selected, the software converts the selected region group to the spatial domain, as indicated by function block **381**. Importantly, this extraction is preferably performed directly from the encoded bit stream and, then, only upon the region group of interest. As indicated by function block **383**, other regions and image data for the sequence will remain in compressed format; this result is graphically depicted by a nondescript image screen **385** having its right bottom corner **387** missing (corresponding to a decoded logo region). Correspondingly, the right side of FIG. **25** indicates the presence of spatial domain regions at reference numeral **389**, as further depicted by an enlarged right bottom image screen corner **391**.

The logo or other image is then combined with the decoded, spatial domain data. Typically, the logo image will correspond exactly in size and configuration to the image area with which it is to be combined; if such is not the case, the logo image preferably is configured as an image that does meet this criteria. The statial domain image data and logo image data are then combined using an opacity measure "α," as indicated by reference numerals **393**, **395** and **397**. This opacity measure determines whether the logo itself will be opaque or translucent. The variable α will typically be zero for all non-logo data, such that the original image (which is weighted by $1-\alpha$) will be unaffected in areas not overlapped by the logo. With this image combination having been performed (typically for an entire GOP at a time), new motion search and compensation is performed (if appropriate, using original frame type) for the new, modified spatial domain data. This data is then bit stream encoded to take the place of image slices which were decoded to the spatial domain for the editing process, and the two signals are added together; these processes are variously indicated by reference numerals **399**, **401** and **403** of FIG. **25**. If appropriate (e.g., the new data has a different compression statistics), the software adjusts buffer size and bit rate parameters for the frame or GOP in a conventional manner, as indicated by block **405**. The output of this process is a compressed video signal **407** which now includes the inserted logo, and where editing was performed without decoding the entirety of each and every frame to the spatial domain. This new signal is depicted in FIG. **25** by an image screen **409** having a cross-hatched lower right corner.

FIG. **26** relates to use of ICRs in color correction. In particular, it is not uncommon for television programs or movies to be "shot" under and expectation that certain colors will be replaced (during editing) with colors which are more pleasing to the eye. With reference to FIG. **26**, it should be assumed that an actor's shirt or torso **411** has been previously defined as an ICR. The process indicated by FIG. **26** might be performed in a post-production house.

FIG. **26** shows an input of compressed video **413**, with a screen **415** pictorially depicting that video; the screen shows the shirt **411** as including one or more particular colors which are collectively denoted by a horizontal-line pattern. It is desired to correct one or more of these hypothetical colors to a different color or colors.

Prior to discussing color correction in the context of ICRs, it might first be helpful to describe a digital color correction process in general. To this effect, as is common in color correction systems, a user of an editing system will supply a color selection angle as well as a replacement color angle, as indicated by boxes **417** and **419**. The color selection angle represents a hue arc (in polar coordinates) that is to be selected for replacement; there are many other mechanisms for selecting colors such as other color plane-based functions (Y-B, Y-R)as well as non-color plane-based functions. A hue trap **421** identifies specific image pixels which do not fall within the color selection angle, and these pixels are not processed for color correction. Pixel colors **423** falling within the color selection angle are subjected to a transform **425**; the transform is defined by the replacement color angle.

To take a simplified example of how this color correction operates, it should be presumed that the shirt **411** has three colors, including white, light red and dark red. The color selection angle **417** might indicate that all reds are to be replaced; further; the replacement color angle **419** might be a narrow range of blues, for example, very light blue to sky blue. In this example, the transformation might result in a wide range of reds being converted to a narrow range of light blues; otherwise stated, the shirt after processing would emerge as white, very light blue, and sky blue in color, with the very light blue replacing the light red and the sky blue replacing the dark red.

Pixels that are color-transformed are then mixed back into the original pixel data via a summing junction **427**, to create new image data.

In the context of ICRs, the color correction process operates very similar to the manner just. described for logo insertion. In particular, as indicated by block **429** of FIG. **26**, a user designates a specific region or regions that are to be the subject of color correction; these regions will be decoded to the spatial domain from the compressed bit stream (as indicated by block **431**), while other regions will remain compressed. Here again, the compressed regions are designated at the left side of FIG. **26** by a block **433** and a picture of an image screen **435** with a blank spot, symbolizing removal of a region for color correction. Similarly, the right side of FIG. **26** indicates the presence spatial domain regions **437** and a picture of the shirt **411**, symbolizing removal of the appropriate region. The shirt is processed for color correction, and new motion estimation and compensation (per reference block **439**) is performed on the color corrected region; the results are bit stream encoded, as indicated by block **441**. The resulting two compressed bit streams are then mixed together via a summing junction **443**, and frame buffer size and bit rate parameters adjusted if necessary (see, e.g., reference block **445**). Finally, the result of the color correction process is a compressed video bit stream **447** that represents color corrected video, depicted by a screen **449** having the color corrected shirt.

FIG. **27** is used to explain fast forward and fast backward functions. While there are many ways of imparting these functions, FIG. **27** shows a process where frame speed is increased by a multiple "Q" via dropping frames and retaining only every "Q_{th}" frame. In FIG. **27**, it is to be assumed that frame speed is to be doubled, and consequently, that only even frames **451** will be retained, and that the video **452** will carry with it a constant, unchanged frame rate. The processes described by FIG. **27** may be applied in conjunction with an ICR signal, particularly where it is desired to take a first image sequence and mix or substitute a second image sequence into one or more regions of the first image sequence. This function will be discussed further below, in connection with FIG. **29**.

The left side of FIG. **27** pictorially shows a sequence **453** of ten frames, half of which **455** are not shaded (and are to be dropped) and half of which **451** are shaded and are to be retained. It should be assumed that some of the frames to be retained depend upon anchor frames which are being dropped; for proper video decompression and reconstruction, these frames need to be segregated and processed during the fast forward or fast reverse process to remove the severed dependency. In FIG. **27**, reference numerals **459**, **461**, **463** and **465** are used to denote this segregation.

To remove severed dependencies, "B" frames are converted to "I," "B-forward" or "B-backward frames, depending upon whether any anchor frames are retained; "P" frames are converted to an independent format. This conversion preferably occurs by completely decompressing the frame of interest to the spatial domain, and then recompressing it in the desired format. Alternatively, a method exists for performing this processing in the compressed domain, as suggested in U.S. Patent application Ser. No. **09/069,596** (now U.S. Pat. No. **6,104,441**, issued Aug. 15, 2000) for "Systems for Editing Compressed Image Sequences," filed on Apr. 29, 1998 on behalf of inventors Susie J. Wee and Bhaskaran Vasudev which is hereby incorporated by reference. These conversion processes are variously indicated in FIG. **27** by reference numerals **467**, **469** and **471**. Once compressed bit stream data is available for the converted frames, it is again mixed with bit stream data for the unmodified frames to form a compressed video output **473**.

FIG. **28** also illustrates a process that is not specific to ICR signals, namely, the splicing of two image sequences together. A first image sequence **475** is illustrated at the left side of FIG. **28**, while a second image sequence **477** is illustrated at the right side of FIG. **28**. The first image sequence forms the original, compressed video input **479**, and the user selects a splice point for each sequence. Because this splice point may result in severance of one or more dependencies (upon an anchor frame), it is necessary to first convert affected frames to remove the affected dependencies. To this effect, FIG. **28** pictorially illustrates in diagonal hatching frames to be retained **481** and **483** from each of the first and second image sequences, as well as retained frames not affected by the splice **485** and retained frames which are affected by the splice (designated by reference numeral **487**). As with the process just described above, dependencies are removed by converting "B" frames to independent, B**20** forward" or "B-Backward" frames as appropriate, and by converting affected "P" frames to "I" frames, in either the spatial or compressed domains (see, e.g., blocks **489**, **491** and **493** of FIG. **28**).

Reverse play functions may be imparted by simply reordering frames in the compressed domain and by performing the conversions just described. "B" frames, however, do not need conversion, but simply some changes to header information to indicate that forward motion vectors become rearward motion vectors and vice-versa.

With this processing background in mind, usage of these and other functions will now be described in the context of an ICR signal, and is explained with reference to FIG. **29**. In FIG. **29**, a compressed video input is designated by the reference numeral **501** and a graphic **503** showing a billboard **505**. In this example, it should be assumed that the billboard has been independently coded and that it is desired to replace the billboard with either a new, second image or entire image sequence **507** that may play at the same rate or a different rate as the compressed video input. To take one example of this process, it might be desired to replace an English language sign (for example, appearing as an advertisement in the background of a soccer game) with a Chinese language equivalent. Alternatively, it might be desired to splice a new video image into existing image frames for the billboard, or to reverse or change the play speed of new video intended for the billboard.

As seen in FIG. **29**, the system receives the compressed video sequence **501** together with region selection information **509** from a user. The region selection information will be used to cause the decoding of a subset of regions in the compressed video sequence, as indicated by block **511**. The remaining regions are not compressed and preferably remain in bit stream format as indicated by block **513** and a screen pictograph **515** (with the billboard region symbolized as missing).

The second image or sequence **507** is modified as desired by the user; preferably, the software affords the user the opportunity to view the second image or sequence overlaid upon the first image., and to crop, scale and change the perspective of the second image. Accordingly, the second image or sequence is adjusted by the user to be roughly compatible with its destination within the video input, as indicated by reference numerals **513** and **515**. The software takes the second image or sequence and maps that information as modified by the user to the dimensions of the decoded spatial regions, and fits substitute image data into the original regions of the video input (or at least within a selected object of the original regions). Preferably, the user is afforded the opportunity (via visual display, zoom and a user interface such as a mouse) to further crop the substitute image data, or to make that data translucent over the original image data. The software also preferably affords the user menu functions to fit accelerated or decelerated display of the second image (sequence) with respect to the original image data (e.g., via frame dropping), or to reverse play of the second image (sequence) with respect to the video input, or to splice several image sequences together to form replacement image data for a region. These functions are indicated by reference numerals **517**, **519**, **521** and **525**.

The lower right side of FIG. **29** contains a pictograph **527** which illustrates the edited data or sequence that is intended for substitution back into, and mixing with, the compressed video input. This data is subjected to new motion estimation and compensation and bitstream encoding, as indicated in FIG. **29** by numerals **529** and **531**. The data is encoded in discrete image slices to take the exact position of those image slices which represented the original billboard. FIGS. **533** and **535** represent the final video output which mixes both regions.

VI. Conclusion.

Importantly, those skilled in video, television and similar fields will recognize that modifications may readily be performed to the embodiment stated above without depart-

ing from the principles of the present invention. For example, while the use of a specific M.P.E.G.-2 encoder and transcoder has been described, it is possible to design other devices operable with other video or audio standards to take advantage of ICRs. It may be possible to use other signal formats and other ICR naming schemes.

Having thus described several exemplary implementations of the invention, it will be apparent that various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements, though not expressly described above, are nonetheless intended and implied to be within the spirit and scope of the invention. Accordingly, the foregoing discussion is intended to be illustrative only; the invention is limited and defined only by the following claims and equivalents thereto.

What is claimed is:

1. In a video compression system, an improvement comprising:

identifying at least two data sets in a video frame that are to be independently encoded;

dividing the video frame into image blocks, and associating each image block with a data set;

motion-compensating the image blocks to generate motion-compensated blocks, but constraining motion vectors for each image block to point only to reference data within the same data set as the image block;

encoding the motion-compensated blocks in a sequential order and beginning a new image slice each time a next motion-compensated block in the sequential order is associated with a different data set; and

producing an output bitstream where image slices are ordered in correspondence with the sequential order of the image blocks.

2. An improvement according to claim **1**, wherein the system is adapted to compress multiple frames of video including an anchor frame and at least one dependent frame that depends upon the anchor frame, and wherein the improvement further comprises:

defining each data set as at least one of an object and a location that occurs in multiple frames; and

constraining motion compensation such that motion vectors for an image block associated with a first data set in a dependent frame point only to image data within an anchor frame also associated with that first data set.

3. An improvement according to claim **1**, further comprising transcoding an input video signal to generate the output bitstream, the input video signal not having at least two data sets defined each represented by mutually-exclusive image slices for a frame, the output bitstream including at least two data sets each represented by mutually-exclusive image slices for the frame.

4. An improvement according to claim **1**, further comprising producing a compressed video output signal from a compressed video input signal by:

decoding image slices that are associated with a particular data set from the input signal, to generate decoded data;

editing the decoded data to generate edited data; and

generating the output signal by

passing image slice data from the input signal for use as part of the output signal for image slices not associated with the particular data set, and

motion-compensating the edited data and constraining motion vectors to point only to the reference data associated with the particular data set; and

inserting into the output signal new image slices representing the edited data to take the place of image slices not directly passed to the output signal.

5. An improvement according to claim **1**, further comprising user interface software that:

permits a user to graphically select one of a spatial region and a specific object in a frame, where the spatial region or specific object occurs in multiple frames; and

automatically identifies in the multiple frames recurrences of the region or object as a single data set that is to be independently encoded.

6. An improvement according to claim **5**, wherein the user interface software includes automatic object tracking software, which takes an object selected by the user, and calculates object position in each one of the multiple frames, notwithstanding any movement of the object from frame to frame.

7. An improvement according to claim **5**, wherein the user interface software includes automatic region tracking software, which takes a region selected by the user, and identifies a like-region across the multiple frames.

8. A method of compressing video to have independently-encoded regions that may be separately extracted from an output video signal without completely decoding the output video signal, said method comprising:

identifying at least two data sets in a video frame that are to be independently encoded;

dividing the video frame into a sequence of image blocks that are to be motion-compensated, and associating each image block exclusively with one data set;

performing motion-compensation upon the image blocks in a constrained manner that limits motion vector dependence to reference data within the same data set;

encoding motion-compensated blocks into substantially non-overlapping image slices, including starting a new image slice each time a next motion-compensated block represents a different data set than the immediately previous motion-compensated block in the sequence; and

producing the output signal from the image slices.

9. A method according to claim **8**, said method adapted to compress multiple frames of video including an anchor frame and at least one dependent frame that depends upon the anchor frame, said method further comprising:

defining each data set as at least one of an object and a location that occurs in multiple frames; and

constraining motion compensation such that motion vectors for an image block associated with a first data set in a dependent frame point only to image data within an anchor frame also associated with that first data set.

10. A method according to claim **8**, further comprising transcoding an input video signal not having independently-encoded data sets to generate an output bitstream having at least two independently-encoded data sets, each image slice of the output bitstream being associated with exclusively one data set and representing an image region of the video frame that does not substantially overlapping with image data associated with any other data set.

11. An improvement according to claim **8**, further comprising producing the output video signal from a compressed video input signal by:

decoding image slices that are associated with a particular data set from the input signal, to generate decoded data;

editing the decoded data to generate edited data; and generating the output video signal by

passing image slice data from the input signal for re-use as part of the output video signal, for those image slices not associated with the particular data set, and

motion-compensating the edited data and constraining motion vectors to point only to the reference data associated with the particular data set; and

inserting into the video output signal new image slices representing the edited data to take the place of image slices not re-used as part of the video output signal.

12. A method according to claim **8**, wherein identifying a data set includes:

graphically-selecting one of a spatial region and a specific object; and

automatically-identifying like-data in other frames of video as part of a single data set occurring in multiple video frames.

13. A method according to claim **12**, wherein automatically-identifying includes tracking an object across the multiple frames by detecting like-data, notwithstanding any movement of the object from frame to frame.

14. An improvement according to claim **12**, wherein automatically-identifying includes defining a like-sized and like-positioned spatial region across the multiple frames.

15. An apparatus, comprising instructions stored on machine-readable media, said instructions when executed controlling compression of a video signal by:

dividing the video frame into of image blocks, and associating each image block with a data set that is to be independently-encoded from other data sets;

motion-compensating the image blocks to generate motion-compensated blocks, but constraining motion vectors for each image block to point only to reference data within the same data set as the image block;

encoding the motion-compensated blocks in a sequential order and beginning a new image slice each time a next motion-compensated block in the sequential order is associated with a different data set; and

producing an output bitstream where image slices are ordered in correspondence with the sequential order of the image blocks.

16. An apparatus, comprising:

a region selection device that identifies subsets of a video sequence that are to be independently encoded from one another;

a motion compensation device that encodes blocks of video data for a frame into motion vector and residual format, but that limits motion compensation to use of reference data associated with the same subset;

an encoding device that builds an output bitstream having discrete image slices separately parsable from the output bitstream, the encoding device sequentially encoding motion-compensated blocks in a manner that each image slice represents motion-compensated blocks associated with a single subset, and that a new image slice is defined each time a next-motion compensated block in the sequence represents a change in subsets that are to be independently encoded.

17. An apparatus according to claim **16**, wherein:

the region selection device defines each data set as one of an object and a location that occurs in multiple frames; and

the motion compensation device constrains motion compensation such that motion vectors for an image block associated with a first data set in a dependent frame point only to image data within an anchor frame also associated with that first data set.

18. An apparatus according to claim **16**, wherein:

said apparatus further comprises a video decoder that decodes an input video signal to the spatial domain to generate spatial domain data; and

the region selector receives the spatial domain data and defines regions therein;

wherein said apparatus is adapted to transcode an input video signal not having independently-encoded regions therein to produce an output bitstream having at least two data sets each represented by mutually-exclusive image slices for the frame.

19. An apparatus according to claim **16**, wherein said apparatus further comprises:

a video decoder that decodes image slices associated with a particular region, to generate decoded data;

an editing device adapted to edit the decoded data to generate therefrom edited data; and

a controller that causes the output signal to be generated by

passing image slice data from the input signal for use as part of the output signal for image slices not associated with the particular data set, and

motion-compensating the edited data and constraining motion vectors to point only to the reference data associated with the particular data set; and

inserting into the output signal new image slices representing the edited data to take the place of image slices not directly passed to the output signal.

20. An apparatus according to claim **16**, further comprising a user-interface that permits a user to select a region by identifying image data in a frame, and that automatically identifies a region based upon image data selected by the user.

21. An apparatus according to claim **16**, further comprising a tracking device that tracks movement of an object from frame-to-frame and automatically associates the object notwithstanding movement between frames to be associated with a region.

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